ELEMENTARY PHYSICAL · GEOGRAPHY

W. M. DAVIS

Joseph S. Davis.
Sept. 5, 1903.

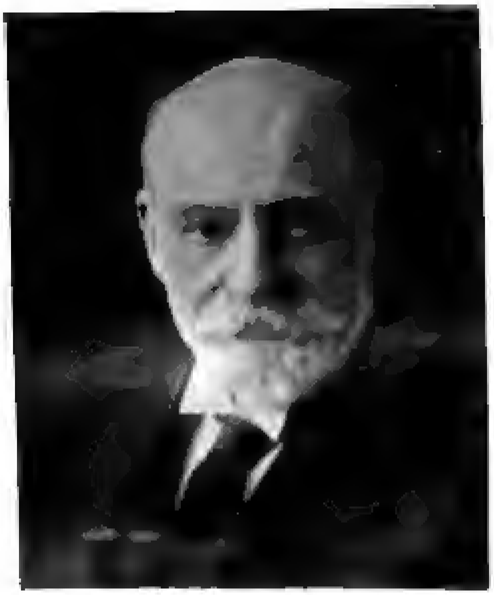

PLATE I. Grays Peak, Rocky Mountains of Colorado

ELEMENTARY

PHYSICAL GEOGRAPHY

BY

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BOSTON, U.S.A., AND LONDON
GINN & COMPANY, PUBLISHERS
The Athenæum Press
1902

PREFACE

THE educational progress of recent years has resulted in two profitable advances for the venerable subject of Geography. A strong feeling has been developed in favor of treating the subject as a whole more rationally than heretofore, and a wholesome desire has arisen in favor of introducing some of its scientific aspects more generally into the school course. A natural accompaniment of this progress has been a demand for text-books that shall present Physical Geography in its modern scientific development as well as in an elementary form. The present book, reduced from the author's "Physical Geography," has been prepared to meet this demand.

The reduction of the earlier book to the present volume has been made chiefly by omitting the more advanced problems and by simplifying and abbreviating the treatment of the remainder; but the chapter on The Atmosphere is here given a greater length than before; and a new chapter is added on The Distribution of Plants, Animals, and Man, considered from a physiographic standpoint. Several topics of a somewhat more advanced nature than the rest of the text, and yet of too great importance to be omitted altogether, are placed in supplements to Chapters I, II, and III.

The plan of this volume is, like that of its predecessor, to give the problems of Physical Geography a rational treatment. The object of this method is not simply to explain physiographic facts, but through explanation to increase the appreciation of the facts themselves. It is, however, not enough that physiographic facts should be associated with their causes; they must also be seen in relation to their consequences if their full importance is to be realized. This relation must not be presented merely as an afterthought, in a detached chapter at the end of a book; it must accompany the presentation of the facts themselves. As Guyot long ago said so well: "To describe, without rising to the causes, or descending to the consequences, is no more science than merely and simply to relate a fact of which one has been a witness." The ideas of cause and of consequence, one preceding, the other following, the physiographic fact, have therefore been held constantly in mind by the author; they should be no less constantly remembered by the teacher and impressed upon the pupil.

Yet, while the causal notion is introduced as far as possible, it must be recognized that certain facts of great importance cannot be really accounted for in an elementary book. Such facts must therefore be described rather than explained. For example, the rotation of the earth and the separation of continental masses from ocean basins are subjects of great importance; they must be described, and their consequences deserve careful attention, but their causes involve speculative investigation of a grade that far transcends the reach of an elementary text. Again,

the simpler phenomena of the tides must be presented; their period may be correlated with the movement of the moon, and the moon may be thus indicated as their chief cause; but the relation between lunar cause and tidal effect cannot be demonstrated to young pupils. A mere outline of theory, with the briefest consideration of the joint action of sun and moon, is introduced in the supplement to Chapter III.

The general circulation of the atmosphere is also far beyond elementary explanation. The circulation may be not unreasonably asserted to depend on the differences between equatorial and polar temperatures; but the more intelligent the pupil, the less can he be satisfied with a simple conventional origin of the prevailing westerly winds. Explanation of this complicated problem is therefore touched upon lightly; while emphasis is given to the elements of which the circulation consists, to the correlation of these elements, and to the deduction of climatic conditions from them. The deflective effect of the earth's rotation is almost universally misunderstood, because it cannot be fully explained in an elementary manner. Its quality is briefly asserted in the text, and on account of its importance a correct explanation in the simplest possible form is inserted in the supplement to Chapter II; but neither this supplement nor that on the tides should be studied by the youngest pupils.

On the other hand, the forms of the lands have not as a rule been sufficiently explained in text-books on Physical Geography. Fifty years ago there was justification for the empirical treatment and even for the neglect of land

forms, in the ignorance of geographers concerning their origin; but the investigations of the last thirty years have thrown a flood of light on this important division of the subject, and to-day it may be treated as rationally as any other. Many problems, formerly obscure, are now seen to be essentially simple and to lie entirely within the reach of elementary treatment. It has thus become possible to extend the explanatory method, long familiar in the study of the atmosphere and the ocean, to the lands as well; and to present plains and plateaus, mountains and volcanoes, rivers, valleys, and shore lines under a rational system. It is believed that this division of the subject is here treated in a manner more systematic and comprehensive and at the same time more simple and reasonable than is the case in any other elementary book. It should however be carefully borne in mind that the explanation of the processes which are involved in the dissection of a plateau, for example, is not introduced merely that the past history of the plateau shall become known, but chiefly that the existing features and especially the systematic correlation of these features shall be better perceived and remembered.

While the list of topics treated will, it is believed, be found exceptionally full for an elementary book, it has nevertheless been necessary to go somewhat against time-honored traditions in omitting certain subjects. Elementary text-books should not present an encyclopedic richness of contents, as if to show the learning of their authors; they should provide a well-selected body of useful information having disciplinary value, pertinent to their subject

and appropriate to young pupils. It has therefore been decided to follow carefully the outline of Physical Geography lately prepared for and published by the National Educational Association, and to exclude certain traditional but irrelevant topics belonging properly to Astronomy, Geology, and Biology. It has also been deemed expedient to omit certain other relatively advanced topics; such, for example, as the distribution of atmospheric pressure, shown by charts of isobaric lines, which have been, it may be said, fashionable since the publication of Buchan's excellent charts of these elements. Important as are the facts thus shown for the more advanced study of meteorology, they have no immediate climatic importance, and their proper use involves so many advanced considerations that they are best excluded from elementary study. Again, there is a chart of cotidal lines, purporting to show the advance of the tidal wave through the oceans, which has been repeatedly copied since it was first published by Whewell in 1833; but this pleasing generalization is omitted here because it was discredited by its very author in 1835, and because it has never since then received the approval of experts in tidal investigation. The best chart of cotidal lines, that of Berghaus' Physical Atlas (reproduced in the United States Coast Survey Report for 1900, Appendix No. 7, Figure 25), leaves the open oceans blank.

The method of presentation adopted is sometimes inductive, sometimes deductive, according to the subject in hand. The inductive method is more largely used, because young pupils are as a rule better able to learn from direct description than from inferences based on general principles. The

exercises suggested for the study of weather maps, in the supplement to Chapter II, are purely inductive; and the several chapters on the development of land forms are largely inductive. But it must not be forgotten that the simpler processes of deduction are perfectly familiar to young pupils, and may be safely employed in teaching where they are appropriate to the topic in hand. It is indeed advisable that the pupil should gain some experience in deduction as well as in induction, and Physical Geography should be recognized as presenting ample opportunity for the exercise and development of both these mental processes. The relation of rainfall to the several members of the atmospheric circulation may be instanced as appropriately deductive, because of the systematic relations of these topics.

The illustrations in the chapters on land forms are of two kinds. The block diagrams represent ideal types. The views of actual landscapes in woodcuts and plates serve as examples of the ideal types. The block diagrams are in several respects more comprehensive than any actual view can be. They show so large an area, from so elevated a point of view, that the relation of the parts to the whole is easily perceived; they omit numerous and frequently irrelevant details by which the pupil's attention might be distracted; they present in the most elementary manner possible the correlation of underground structure and surface form; and in this respect they are far superior to mere geological sections, in which the land surface is represented only by a profile line which few young pupils can translate into a topographic form. Exercises in

drawing simple outline maps from the block diagrams are frequently suggested, in order to insure the recognition of the essential features of the type. It will also be found useful to ask the pupil to indicate the relation of a view to its type diagram, as is done in the text for Figures 71 and 73, and for Figures 141 and 142.

The questions inserted in the text are intended to aid the pupil in learning his lessons; the questions at the end of the chapters are intended for use by the teacher in tests and reviews after the lessons have been learned. If it is desired to extend the time devoted to Physical Geography by classes whose average age is somewhat above that for which this book may be used, all of the text, as well as the supplements to Chapters I, II, and III, may be studied in full. If it is desired to shorten the course, the supplements may be passed over, the number of map drawings may be decreased, and certain sections that are concerned with relatively advanced topics (for example, Sections 99, 103, 107, 124) may be omitted.

The teacher will find it practically convenient to indicate by a brief reference in the page margin the books and maps mentioned in the Appendix. The examples there referred to should be supplemented as far as possible by local examples observable at or near the school. Illustrations of many topics treated in Chapter II will be found in the ordinary observation of passing weather phenomena. Many of the activities of the lands may be illustrated by local excursions, for which the autumn is a convenient season; while examples of the land forms seen in the school neighborhood should be studied in the spring.

Inasmuch as land forms vary greatly from place to place, no general guide can be of service in this division of the subject; but teachers are advised to make themselves familiar with their school district by frequent excursions, and to use as far as possible all the appropriate illustrations that they discover.

The author desires to express his thanks to a number of his correspondents who have supplied photographs from which several of the plates have been copied, and also to a number of teachers and others who have accepted the fatiguing task of criticising his manuscripts and proof, particularly to Professor J. B. Woodworth of Harvard University, Mr. M. Grant Daniell of Boston, and Mrs. M. A. L. Lane of Hingham. The questions at the ends of chapters have been prepared by Mr. R. H. Cornish, of the Girls' High School, New York, whose practical acquaintance with school work insures their value.

W. M. D.

HARVARD UNIVERSITY,
March, 1902.

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ELEMENTARY PHYSICAL GEOGRAPHY

CHAPTER I

THE EARTH AS A GLOBE

1. Introduction. — Physical geography treats of the various features of the earth that influence the manner in which man lives upon it. Hence it must consider the form of the earth as a whole, the climates of its different parts, its oceans with their waves and tides, and the forms of its lands.

It is the plan of this book to describe the more important kinds of physical features on the earth, to refer them to their causes in natural processes, and to trace them to their consequences as seen in the condition of mankind.

2. The Shape of the Earth. — The people of savage races, when they think at all about the shape of the earth, generally imagine it to be a great plain, varied by hills and mountains and surrounded by the sea; for that is the appearance of the lands when seen from some high point, with mountains rising to greater heights, lowlands extending to the seashore, and the ocean stretching beyond.

The people of an ignorant race usually regard the place where they live as the center of the great earth plain. Of

the ocean they know little; its further parts are invisible and mysterious and are often thought of as much more dangerous than those which border the solid lands.

Among the earliest observations that led to a knowledge of the true form of the earth were those made by the Greeks.

The great philosopher Aristotle, who flourished about the middle of the fourth century B.C., made an ingenious use of the eclipses of the moon to determine the form of the earth. He knew that the earth cast a great shadow stretching away into space on the side opposite the sun; and that whenever the moon, in its movement around the earth, entered this shadow it was hidden or eclipsed, because it then no longer received the sunlight that ordinarily makes it visible. He noted that the edge of the earth's shadow on the moon is a curved line, and thus he knew that the earth must have a curved surface, such as a globe has.

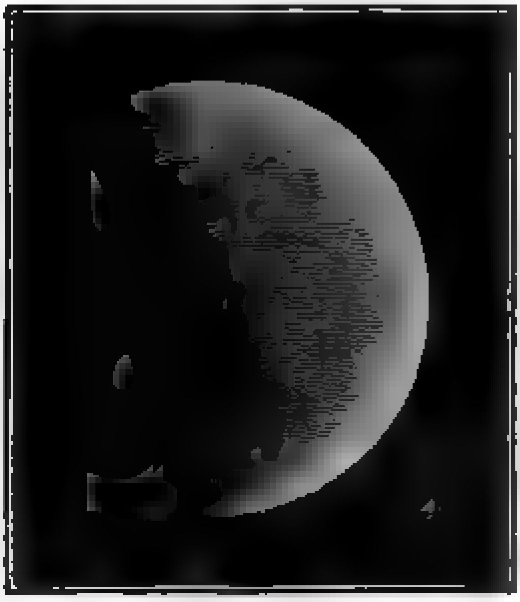

FIG. 1. Eclipse of the Moon, showing the Curved Edge of the Earth's Shadow

The moon, revolving about the earth once in twenty-eight days, is not eclipsed every time it is opposite the sun, for it usually passes a little to one side of the earth's tapering shadow.

The familiar argument for the globular form of the earth, based on the disappearance of the lower part of

distant vessels at sea, was not mentioned by ancient writers until about the beginning of the Christian era.

3. Size of the Earth. — The earliest recorded measurement of the size of the earth was made by a Greek philosopher in the third century B.C., who found its diameter to be about 8000 miles. The knowledge thus gained by the wise men of the ancient Mediterranean countries concerning the size and shape of the earth was unknown to the rest of the world and was afterwards forgotten; but it was regained about the time of Columbus.

The proof of globular form by sailing around the earth, or circumnavigation, was first accomplished in the sixteenth

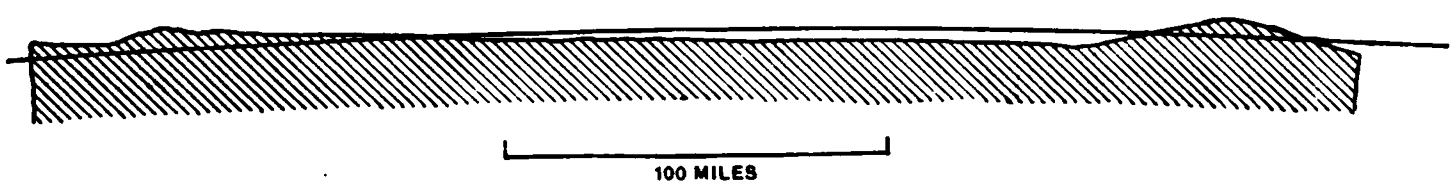

FIG. 2. Height of Land and Depth of Sea compared to Curvature of Earth's Surface

century, when the Philippine islands were discovered. What can you learn about Magellan? In later centuries nearly all parts of the earth have been explored, and its size and shape have been accurately measured. Its diameter is about 7912 miles.

4. Unevenness of the Earth's Surface. — The broad depressions between the continents, in which the oceans are gathered, are of small depth compared to the diameter of the earth. The continents have many mountains and valleys, but the general surface of the lands does not depart greatly from a globular form, such as is so well shown by the surface of the oceans. This is fortunate,

for on very uneven lands the long ascents and descents between the higher and lower parts would make travel and transportation enormously difficult or utterly impossible. It is difficult enough to cross over the existing mountain ranges, whose highest peaks rise hardly more than $\frac{1}{1000}$ of the earth's radius and whose passes are much lower; if their height were $\frac{1}{100}$ of the earth's radius, they would be absolutely impassable.

Exercise. With chalk and string draw a circular curve of 4 feet radius on a blackboard. If the chalk line is $\frac{1}{40}$ inch wide, it will represent the average depth of the oceans (2 miles); if it is increased underneath here and there to $\frac{1}{15}$ inch, it will indicate the greatest known depths of the oceans (about 5 miles). Small inequalities rising $\frac{1}{100}$ to $\frac{1}{15}$ inch above the outside of the curved line will represent the altitude of the continents and their mountains above sea level. At a distance of 20 feet the departure of the curve from a true circle will be hardly noticed. So the earth would seem smooth and truly globular if we could see it from a great distance.

5. Consequences of the Size and Shape of the Earth. — The earth is so large that savage tribes, even on the same continent, may remain in ignorance of each other for centuries. Each tribe then comes to have its own way of doing things, appropriate to its local surroundings. Thus differences of language and customs have originated. But since railroads and steamships have been invented the earth may be considered a relatively small body; an active traveler may now visit nearly all its larger districts in his adult years.

The civilized nations have become well acquainted with each other, because the earth's surface is so nearly level

that movement over it is possible. They now maintain an international postal service, by which nearly 200,000 post-offices are in regular communication with each other. The Roman alphabet is used by many nations, although their language may be different. The use of Arabic numerals is even more extended. The metric system of weights and measures is already widely introduced and will probably be adopted by all advanced nations during this century.

The products of remote regions are exchanged, even from opposite sides of the earth. The wheat of one continent furnishes flour to another. Australian wool and meat are sold in London. The manufactures of Europe and the United States are distributed all over the world. On a more uneven earth it might be impossible to develop a world-wide commerce.

6. The Earth's Attraction, or Gravity.—It is the attraction of the earth, or terrestrial gravity, that causes bodies to have weight and to fall when not supported. Recognizing the earth to be a globe, "down" is toward its center, or in the direction that bodies are pulled by its attraction, as indicated by a plumb line; "up" is away from the earth's center, or against the pull of gravity. A level surface, like that of a quiet body of water, a calm lake or ocean, represents a part of the convex or globular surface of the earth; it is everywhere at right angles to the up-and-down, or vertical, lines.

The stems and trunks of plants grow "up" against the force of gravity. Even on hillsides trees tend to grow

erect and not square out from the sloping surface. Many parts of the skeletons of men and animals, as well as many of their muscles, are especially adapted to bear the strain that is exerted upon them by the downward weight of the body. The habit of lying down to sleep has been formed chiefly to rest the muscles that are in action while a person is standing. The walls of buildings are built vertical, because in that position they will stand most securely.

7. The Earth's Rotation and its Consequences. — Few discoveries ever made by man have been more opposed to his early beliefs than that the earth turns or rotates on its axis once a day and that it moves or revolves around the sun once a year; for nothing is more natural than to suppose that the firm earth stands still in the center of the universe and that all the bodies of the sky turn around it. But it has been proved that the apparent turning of the sun and stars around the earth from east to west is due to the actual rotation of the earth from west to east. One may gain a false impression of the same kind while looking from the window of a smoothly running train, when it seems as if the landscape moved backward instead of the train forward. The northern end of the imaginary line, or axis, on which the earth turns is directed (almost) toward the North Star in the sky.

A little over two centuries ago it was discovered that the earth is not a perfect sphere, but is very slightly flattened at the poles. The equatorial diameter is 7926 miles; th[illegible] diameter, 7900 miles. This was explained by [illegible] a result of the earth's rotation, and it may be

taken as one of the best proofs that the earth and not the sky turns.

8. Day and Night. — The sun illuminates one half of the earth, leaving the other half in shadow. As the earth turns around, passing from the light into the darkness, one perceives the succession of day and night every time a rotation is made. The time at which the sun comes in sight over the eastern horizon is sunrise; when it disappears below the western horizon, sunset.

The succession of day and night, resulting from the rotation of the earth, has given man and many animals the habit of working in the light and resting in the darkness. The period of the earth's rotation furnishes a natural unit of time, easily recognized and counted, and everywhere alike and constant. Clocks and watches are regulated to keep time with the earth's turning. The hour hand of timepieces in common use turns once for the average duration of daylight, and once for the average duration of darkness.

The rotation of the earth, causing sunrise and sunset, suggests a natural system of directions by which the relative positions of different places may be indicated. The cardinal points, east and west, north and south, are in a more or less definite way recognized by most peoples of the world.

The sun rises through the eastern half of the sky during the morning and sinks through the western half in the afternoon. Midday is the moment when the sun passes the north and south line that divides the eastern from

the western half of the sky. The sun then reaches its greatest height above the horizon; and, hence, at this moment a vertical rod casts the shortest shadow.

Exercise. Set up a vertical post in level ground (or a square-cornered box on a level table). Mark the successive positions of the end of the rod shadow (or of a corner of the box shadow) every ten or fifteen minutes for an hour or more before and after noon. Draw

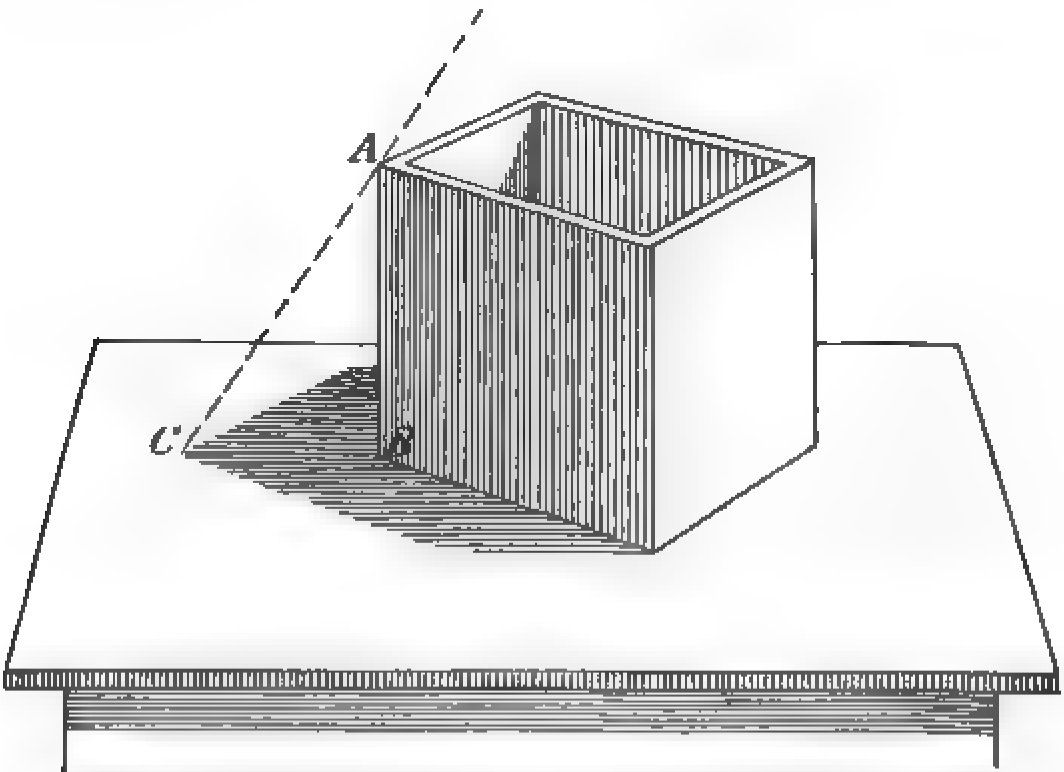

FIG. 3 The Shadow of a Box, showing the Altitude of the Sun

a line through the marks. Find the shortest line from the base of the post (or from the lower corner of the box) to the line through the marks. This shortest line is a true north line, or meridian (mid-day) line. On the following day note the moment when the shadow falls on the meridian line; that moment is local solar noon, or mid-day. A watch then set to 12 o'clock will mark local solar time.

9. Latitude and Longitude. — The north or meridian line would, if followed in the direction away from the

sun, lead to the north pole; in the opposite direction, to the south pole. All meridian lines therefore meet at the poles. When prolonged around the earth they are called meridian circles. Lines drawn at right angles to the meridians will run parallel to each other, east and west, around the earth and are therefore called parallels. The earth being globular, a simple system of meridians and parallels may be imagined to form a network of circles over its surface.

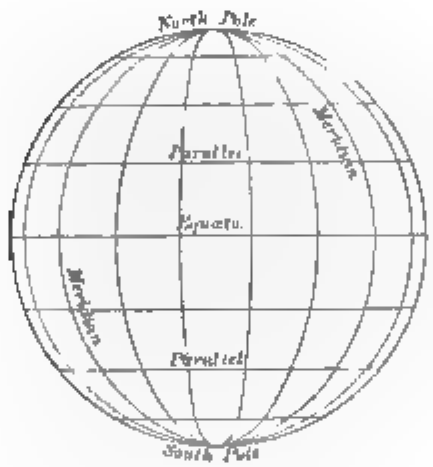

Fig. 4. Meridians and Parallels

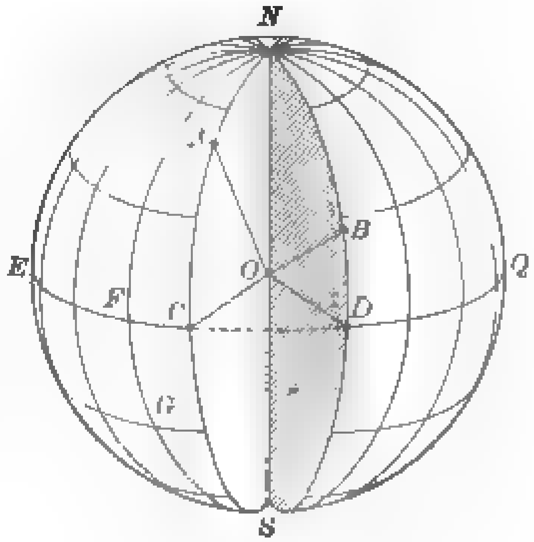

Fig. 5. Latitude and Longitude

It is by reference to these lines that the relative positions of places on the earth's surface are determined.

The parallel that lies halfway between the poles is called the equator. It divides the earth into the northern and southern hemispheres (half-spheres). The latitude of a place is its distance north or south of the equator. It is measured along the meridian of the place and is counted in degrees, ninety to a quarter circle. In Figure 5 the latitude of *A* is the number of degrees in the arc *AC*, or the angle *AOC*. What is the latitude of *B*?

Low latitudes are near the equator in either hemisphere; high latitudes, near the poles; middle latitudes, roughly midway between pole and equator in either hemisphere. (See page 89.)

The longitude of a place is the number of degrees by which its meridian is east or west of a standard or prime meridian. The meridian of the national observatory of Great Britain at Greenwich, a suburb of London, is now very generally taken as the standard. The longitude of a place is measured from the prime meridian east or west along the equator to the meridian of the place and is counted in degrees, 180 to half a circle, or in hours, 12 to a half circle. If *NACS*, Figure 5, is taken as the standard or prime meridian, the longitude of *B* is measured by the arc *CD* of the equator, or by the angle *COD*, between the local and the prime meridians. Is *B* in east or west longitude? What is the latitude of *G*? What is its longitude?

Practical Exercise. A useful illustration of the manner in which maps are made is given by providing a number of outline maps, showing parallels and meridians (latitude and longitude lines), on which the latitudes and longitudes of a number of points are to be platted. The points should be selected on the boundary of some state or country; their positions may be taken from an atlas and written upon a blackboard. By drawing a line through the points thus platted each pupil will have constructed a rough map of the chosen boundary. Rivers and cities may be similarly located.

Land surveys, by which the boundary lines of farms and house lots are marked out, are best made with reference to the local meridian, or north line. Navigators have

daily occasion to determine their position with respect to the network of meridians and parallels, in order to follow the desired route, to avoid islands and headlands, and to reach their intended port.

The boundaries of thinly settled parts of civilized nations and states are often defined by meridians and parallels, as between the western parts of the United States and Canada, as well as between many of the states themselves, and between the various parts of Canada and Australia. Thus great advantage is taken of the simple globular form and regular rotation of the earth.

10. Relation of the Earth to the Sun.—The sun, glowing with extreme heat, has the enormous diameter of 866,500 miles. If the earth were placed at the sun's center, and the moon were moving around the earth at its actual distance of 240,000 miles, the sun would still reach almost 200,000 miles beyond the moon on all sides.

So huge a body is a fitting center for the earth to move around. Even at the great distance of 93,000,000 miles, the brilliant sun gives abundant heat and light to the earth. This distance is so great that an express train traveling from the earth fifty miles an hour could not reach the sun in less than two centuries.

The earth travels or revolves around the sun every year in a nearly circular path, called its orbit. In order to accomplish this long journey of over 600,000,000 miles, our globe rushes along at a speed of 18.5 miles a second, or over 1,500,000 miles a day. As the motion is accomplished with perfect smoothness, and as we move with the

earth, we are as unconscious of this rapid movement in the annual orbit as we are of the diurnal rotation on the axis.

Exercise. Lay a large sheet of paper on a table; draw a line through the middle of the sheet. Let this line represent a distance of 200,000,000 miles. On each side of the middle of the line set up a pin, so that the distance between the pins shall represent 3,000,000 miles ($\frac{3}{200}$ of the length of the line). Lay off 189,000,000 miles on this scale on a thread and knot together the ends of this length, so as to make a loop. Lay the loop over the pins, stretch it tight with a pencil point, and thus guided draw a curve around the pins. The line thus drawn is nearly circular and represents the true form of the earth's orbit. Take out the pins. Around one pin hole draw a circle to scale, somewhat less than 1,000,000 miles in diameter; this will represent the sun. On the same scale the earth would be a small dot. The points where the orbit is crossed by the middle line show the greatest and least distances of the earth from the sun. What are these distances? The point nearest the sun (perihelion = "near-sun") is passed on January 1; the farthest (aphelion = "far-sun") on July 1.

The stars are distant suns, shining by their own light. Most of them are much more than a million times as far from the sun as the earth is. They are so exceedingly remote that a ray of light which travels from the sun to the earth in eight minutes would be about three and a half years on the journey to us from the nearest star. Many of the stars are believed to be larger than the sun.

11. Relation of the Earth to other Planets. — There are a number of other bodies which, like the earth, move around the sun. Like the earth they do not shine by their own light, but only by sunlight that falls on them.

At night these bodies look like stars, except that they twinkle less. Their light is brighter or fainter according to their size and their distance from the sun. The telescope shows them to be of globular form, like the earth. Their movement among the stars, easily noted from month to month, shows that they revolve around the sun in the same direction that the earth does. The spots that may sometimes be seen on the sun show that it also rotates on its axis in a little less than a month, in the same direction that the planets move around it.

The planets that may be easily seen without a telescope are named Mercury, Venus, Mars, Jupiter, and Saturn. Mercury, Venus, and Mars are smaller than the earth; Jupiter and Saturn are much larger. Mercury and Venus are nearer to the sun than the earth is; Mars, Jupiter, and Saturn are more distant; and two other large planets, Uranus and Neptune, are farther away than Saturn. The planets that are near the sun revolve around it in a shorter time (or "year") than those further away. The small planets, Mercury and Venus, are believed to rotate very slowly on their axes, so that their "day" is long. The large planets, Jupiter and Saturn, rotate rapidly, so that their day is about half as long as ours.

The moon is a planetlike body which revolves around the earth while the earth revolves around the sun. The moon is therefore called a satellite (= a follower), because it accompanies the earth. Its diameter is about a quarter of that of the earth; its distance from the earth is about 240,000 miles. Mercury and Venus have no satellites, Mars has two very small ones, Jupiter has five, Saturn has eight.

It is thus found that the earth is not a solitary body, unlike all others, but that it occupies an intermediate position in a large family of similar bodies.

Diagrams may be constructed to represent the relative sizes of the planets and their relative distances from the sun by means of the following table. Diameters are given in thousands of miles; distances in millions of miles.

	Distance	Diameter		Distance	Diameter
Sun	0	866.	Jupiter . .	480	85.3
Mercury . .	36	3.0	Saturn . . .	881	70.1
Venus . . .	67	7.6	Uranus . .	1772	30.9
Earth	93	7.9	Neptune . .	2770	34.0
Mars	141	4.2			

12. The Solar System. — The sun, the planets, and their satellites form a group of bodies called the solar system. The resemblances of form and motion among the planets and satellites are so numerous that it is believed that they have all had a common origin. It has been thought that these bodies, and the sun also, have been formed by the gathering together of materials that were once scattered through an enormous space, like a vast cloud or nebula. This interesting and famous theory is called the nebular hypothesis, but it is not successful in explaining all features of the solar system.

The stars resemble the sun in many ways. It is believed that each star may be accompanied by a larger or smaller family of planets; and hence the number of earth-like bodies in the universe is probably very large.

13. Structure of the Earth. — Rocks of one kind or another are often seen at the surface of the lands; or if the surface is covered by soil, rocks may be found beneath the soil in wells and railroad cuts. The deepest mines and borings, reaching about a mile beneath the surface, pass through similar rocky materials. Hence it is believed that the body of the earth is composed of rock.

This great globe of rock is covered with a considerable quantity of water and air lying upon its surface and forming its oceans and its atmosphere. The oceans are not continuous all over the earth; but are gathered on the lower parts of the surface, while the higher parts rise somewhat above the oceans and form the continents. The atmosphere entirely incloses the oceans and the continents, rising far above the highest mountains.

Thus the earth as a whole consists of matter in three different states, — solid, liquid, and gaseous. The liquid portion, or water, is also known as a solid when it freezes and forms ice; and as a gas when it evaporates and mixes with the air as invisible water vapor. The solid portion, or rock, is seen as a liquid when it comes forth from volcanoes at high temperatures as molten lava. The gaseous portion, or air, is always gaseous under natural conditions, but it may be artificially reduced to a liquid or a solid by subjecting it to heavy pressure at extremely low temperatures.

There is a certain amount of mixture of rock, water, and air, or of the solid, liquid, and gaseous parts of the earth. Some solid substances have been dissolved by the action of water and are now found in the oceans. A small

amount of rock in very fine particles, or dust, is raised from barren surfaces by the wind and carried far and wide; the finest particles remain long in the air, slowly settling but often lifted again by rising currents. Water and air penetrate all pores and crevices that they can find in the rocky sphere. Water vapor is always present in the atmosphere in small and variable proportion; it becomes visible when chilled and condensed, forming small liquid or solid particles in cloud, rain, or snow. A small amount of air is dissolved in the oceans; but for this, the fish and many other animals that live beneath the surface of the sea could not breathe.

14. Underground Temperatures. — Temperatures measured in deep wells and mines show that the earth becomes warmer beneath the surface. The average increase of temperature downwards is about 1° for sixty feet. At great depths, such as twenty or a hundred miles or more, very high temperatures would be expected; they are proved to occur by the melted lavas that rise and escape in volcanoes. It is therefore supposed that the great interior rocky mass of the earth is hot enough to be melted, although the enormous pressure of the outer parts may prevent the expansion that would be needed to make it liquid. It may thus be forced to remain solid in spite of its high temperature. The outer and cooler part of the earth is often called its crust.

Just as a hot ball of iron will cool when it is hung in the free air, so the earth must be slowly cooling as it moves through cold space. It is very probable that the

unevenness of the geosphere, in ocean basins, continents, and mountains, is in some way the result of a sort of settling and bending of the crust, slowly caused by the long cooling of the earth.

15. Age of the Earth. — It is impossible to say what the age of the earth and the solar system is, but it certainly should be reckoned in millions and millions of years. There is every reason to believe that the sun and the planets existed for an indefinitely long period before the condition of the earth's surface was such as to allow the habitation of the planet by plants and animals. It is well proved by the prints or fossils of various plants and animals in ancient rock layers that these lower forms of life existed upon the earth for a vast length of time, millions and millions of years before man appeared. It seems entirely possible that other planets may have once been, may now be, or may yet come to be occupied by inhabitants of some kind.

16. The Earth as a Magnet. — If a magnetized bar of steel is balanced on a pivot and placed in the neighborhood of a large magnet, the direction in which the small bar points will be determined by its large neighbor. This may be tested by changing the relative positions of the two. If the small magnet is left alone, it will in most parts of the earth turn until it points about north and south. This is because the earth acts as if it were a huge magnet and so determines the direction in which smaller magnets tend to stand.

The behavior of suspended bar magnets makes them very valuable in determining directions, especially in

cloudy weather at sea. A magnet mounted in a convenient case is called a compass, the bar being called a *needle.* In the mariner's compass a card bearing the letters indicating the points of the compass lies on the needle and turns with it.

The needle seldom points along a true meridian toward the pole, but somewhat to one side or the other of a meridian, in a direction that if followed will lead toward the "north magnetic pole" (about twenty degrees away from the true north pole toward Hudson bay) or toward the "south magnetic pole" (about the same distance from the true south pole toward New Zealand). The difference between true north and magnetic north at any place may be determined by comparing the direction of the midday (or shortest) shadow cast by a vertical pole with the direction of a compass needle.

FIG. 6. Mariner's Compass

17. The Aurora. — During clear nights, especially in winter time, the northern part of the sky is sometimes illuminated by an arch of whitish, greenish, or rosy light. Moving streamers of light, whitish or colored, are seen between the arch and the higher parts of the sky. This appearance is called the aurora borealis, or "northern

lights." The aurora is more frequent and brilliant in high northern latitudes than in temperate latitudes. A similar appearance in far southern latitudes is known as the aurora australis. In both cases the middle of the auroral arch is seen in the direction of the magnetic pole. From the disturbance of delicate magnets during an auroral display it is believed that the lights are due to a faint electric discharge controlled by the magnetic forces of the earth.

SUPPLEMENT TO CHAPTER I

18. Proof of the Globular Form of the Earth by Observations of the Stars. — Looking upward from the earth, the sky seems like a hollow shell of vast size, carrying the sun by day and the stars by night. The earth may be thought of as standing at the center of the great sky shell, so that an observer at any point sees only half the sky above him, the other half being hidden beneath the earth. The lower border of the visible half of the sky is called the horizon, and the plane that extends outward from the observer to the sky border is called the plane of the horizon.

By watching through the night the Greek philosophers saw the stars rising in the eastern side of the sky and descending in the western; and they concluded that the sky, carrying the stars with it, turned around the earth once a day. It is now known that the earth turns, and not the sky.

In order to understand this clearly the pupil should learn by observation something of the diurnal movement of the sun, moon, and stars across the sky and should recognize that their paths are parts of slanting circles.

Perception of the essential facts is greatly aided by the use of a "pointer," three or four feet long, tied at one end to the top of a stake about which it may turn freely. Direct the pointer toward the sun at different hours of the day. Repeat this until the (apparent)

movement of the sun becomes familiar. Then sweep the pointer more rapidly through its successive positions. Infer the directions it would assume if the sun could be observed all night. Infer the attitude of a line, or axis, about which the pointer turns. This line must be parallel to the axis on which the earth turns.

The (apparent) diurnal rotation of the stars is best shown by home observations. Direct a pointer toward a star at a convenient evening hour. Watch the star for five or ten minutes and note its change of position. The next evening begin the observation fifteen or twenty minutes earlier. How can the facts thus observed be best accounted for? The movement of the stars as seen from different places must next be considered.

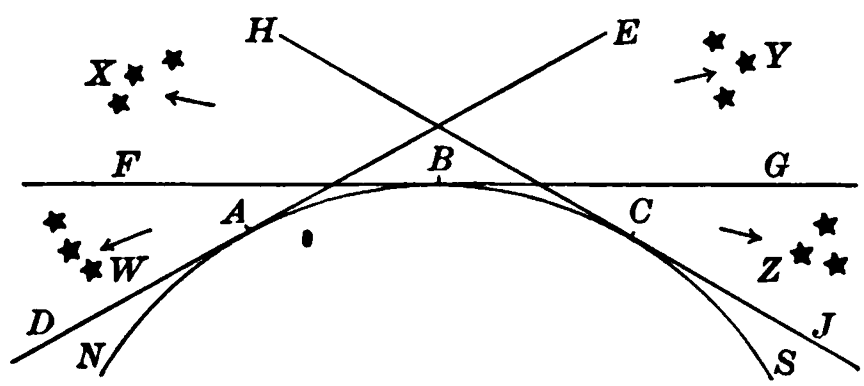

FIG. 7. Globular Form of Earth shown by Visibility of Stars

When one travels southward from *B* to *C* it is found that new groups of stars, *Z*, Figure 7, not visible before, come into sight over the southern horizon, while other groups, *X*, that had before been seen over the northern horizon are no longer visible. From this it is concluded that the plane of the horizon *HJ* at the new point of observation is not parallel to the plane *FG* at the first point, and that the surface of the earth must be convex instead of flat. Hence the earth as a whole must be a globe or sphere.

Changes of this kind are easily recognized in traveling from the northern to the southern border of the United States, or farther south into Mexico or Cuba. They may be verified by correspondence between different schools, several hundred miles apart north and south. What changes would be noted in traveling northward from *B* to *A*?

QUESTIONS

SEC. 1. What are the chief subjects that are taught in Physical Geography?

2. What is the view generally held by savage races as to the size and shape of the earth? When were correct notions first gained as to the earth's shape? How did Aristotle infer the earth's shape? What must be the relative positions of sun, earth, and moon when the moon is eclipsed? Why is the moon not eclipsed every month?

3. When was the earth's size first determined? When and by whom was the earth first circumnavigated? Name some of the places then discovered.

4. Describe the general form of the earth. State the relation of its mountain heights and ocean depths to its diameter. Does the earth's form favor travel and transportation? How?

5. How are savage tribes affected by the size of the earth? In what ways have civilized nations become associated with one another?

6. What is meant by "up" and "down"? How is the surface of a quiet body of water related to the direction of gravity? How is the position of tree trunks and house walls related to the direction of gravity? What consequences of the action of gravity are seen in men and animals?

7. What is the belief of primitive man about the position of the earth? What are the facts? What is the effect of the earth's rotation on its form?

8. What is the cause of day and night? What is the most natural unit of time? What habits of man and animals result from the earth's rotation? How are the cardinal points related to the earth's rotation? What is the position of the sun at midday? How are midday and true north determined? Given a north and south line, how can you determine east and west?

9. Define meridian line, meridian circle, poles, parallels, equator. What is latitude and how is it measured? What is meant by low,

middle, and high latitudes? What is longitude and how is it measured? State some of the practical uses of meridians and parallels.

10. Compare the sun's size with that of the moon's orbit. Calculate the time needed for an express train to reach the sun. What is the earth's orbit? What is the earth's orbital velocity? How is it found? What are the stars? What can be said of their distance from us?

11. How are the planets distinguished from the stars? Which planets can be seen without a telescope? Name the planets in order of distance from the sun. Which are larger, which smaller, than the earth? Compare the "day" of Jupiter and of Saturn with our day; the "year" of Venus and of Mercury with our year. State the size and distance of the moon.

12. What is the solar system? What features are possessed in common by its members? What do these common features suggest?

13. Of what is the great body of the earth believed to consist? Why? What is meant by the earth's crust? What are the three states of matter? Give examples of them. What are the chief divisions of the earth?

14. What is known about underground temperatures? At what rate does temperature increase downward? What is the supposed condition of the earth's interior? What relation is suggested between the earth's surface form and its interior temperature?

15. What may be said of the earth's age and of life on the earth?

16. How is a small balanced magnet affected by a large one? How will a balanced magnet stand when alone? What is a compass? What are the magnetic poles? Where are they? How far to one side of the meridian does the compass point at your school. Does it point east or west of the true meridian?

17. Describe the aurora borealis. How is it related to the magnetic pole?

CHAPTER II

THE ATMOSPHERE

19. The Atmosphere is a light and transparent mixture of gases, known as air. It rests upon the lands and seas, forming the outermost part of the earth. It takes part in the earth's daily rotation and yearly revolution.

Many processes that take place on the lands and seas depend on the atmosphere. The waves and currents of the ocean are caused by the winds; the soil that covers so large a part of the lands results from the decay of the underlying rocks, largely through the action of moist air. Rainfall, so important in many ways, is supplied by moisture received from the oceans and carried about by the movements of the atmosphere.

The atmosphere far overtops the highest mountains. Meteors, or "falling stars," — small scraps of matter dashing toward the earth from outer space — are heated by rushing through the air at enormous speed, so that they become luminous. They are sometimes seen at heights of more than a hundred miles, showing that some air reaches that great altitude.

Cloud, haze, and dust make the lower air more or less turbid and often shut out a great part of the sun's rays; but when the air is clear it is so transparent that sunlight is strong even at the bottom of the atmosphere.

20. Composition of Air. — Air consists of a uniform mixture of gases in which a small and variable quantity of water vapor is usually present. The chief gases are nitrogen and oxygen, which constitute about four fifths and one fifth, respectively, of the atmosphere.

Fire is the result of an active combination of some burnable substance with the oxygen of the atmosphere. The heat thus developed may produce light, or it may convert water into steam, and the expansive force of the steam may be used to drive engines and many kinds of machinery.

All animals and plants breathe in air and use some of its oxygen to combine with part of their substance in a very slow combustion, which produces a slight amount of heat, but no fire. Thus all forms of life, animal and vegetable, depend upon the oxygen of the air, as well as upon their food, to keep them alive.

Carbonic dioxide, constituting less than a thousandth part of the atmosphere, is nevertheless important for the growth of plants. The carbon taken from this gas by growing plants makes a large part of their structure.

21. Pressure of the Atmosphere. — Although the air is invisible, it is attracted by the earth and exerts a pressure of about a ton to the square foot upon the surface on which it rests. The total pressure on a man's body amounts to several tons; but this is not felt because the air within the body exerts a corresponding pressure outward. The air is so easily moved that little resistance is noticed when one walks through it; but fast railroad

trains are much impeded by the resistance of the air that they have to push rapidly aside.

The pressure of the atmosphere is measured by the barometer. This instrument is of two kinds. The mercurial barometer, Figure 8, consists of a glass tube, somewhat more than thirty inches long and closed at one end. It is prepared by filling the tube with mercury, closing the open end with the finger, and inverting the tube; the open end is then placed in a vessel of mercury and the finger is withdrawn. The mercury sinks a little below the closed upper end of the tube, leaving an empty space, or *vacuum*, above it. The mercury column must press down on part of the mercury in the vessel just as much as the air presses on any equal part of the mercury surface. Thus the height of the mercury column, measured by a scale, may be taken as a measure of the pressure of the atmosphere.

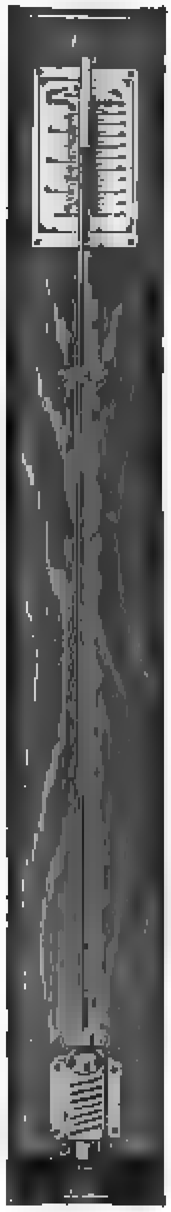

FIG. 8
Mercurial Barometer

The aneroid barometer consists of a small box, from which the air has been exhausted. A variation in the pressure of the atmosphere causes a slight change in the shape of the box. The change is magnified by a series of delicate levers, by which an index is moved on a dial. The reading indicated on the dial then shows the pressure of the atmosphere.

The ordinary changes of atmospheric pressure, such as may be seen to accompany weather changes by reading a

barometer from hour to hour and from day to day, are seldom more than a thirtieth or a fifteenth of the total pressure.

If a barometer is carried up a lofty mountain, leaving much of the atmosphere beneath it, the pressure of the overlying atmosphere is found to be much reduced. An ascent of a thousand feet causes a lowering of about an inch in the barometric column. Thus barometers may be used to measure mountain heights.

Although very light, the air supports the flight of birds and insects. The wind drives sailing vessels and windmills. In dry regions, where the ground is not covered with vegetation, the shape of the surface is changed by the long-continued action of the wind in drifting sand and dust from place to place.

22. Elasticity of the Air. — Air is extremely elastic, changing its volume with every change of pressure. Its lower part is compressed by the weight of the overlying parts, so that much more air is contained in a cubic foot at sea level than at a height of three miles. This is expressed by saying that the density of the lower air is greater than that of the upper air. A cubic foot of air at sea level weighs about 0.075 pound, while at three miles above sea level its weight is only about half as much, and at an altitude of a hundred miles the air must be almost imperceptible.

Men and animals living on high plateaus have become accustomed to the rarity or thinness of the air around them. There are villages on the plateau of Tibet and in

the higher valleys of the Andes at heights of from 12,000 to 14,000 feet, where the density of the air is hardly two thirds of that at sea level. Mountain climbing at altitudes above 20,000 feet is almost impossible, from the difficulty of breathing the thin upper air.

It is by slight wavelike movements in the air that sound is transmitted. So quickly is the wavelike disturbance passed on that sound travels a mile in five seconds. So easily is the air disturbed that a locust (cicada) may set hundreds of tons of air vibrating perceptibly to our nerves of hearing. When the volcano Krakatoa, between Java and Sumatra, exploded in August, 1883, sounds were heard for 2000 miles, and atmospheric waves, detected by slight changes of pressure in barometers, passed three times around the earth.

23. Colors of the Atmosphere.—The clear atmosphere is so transparent that the light of faint stars can pass through its whole thickness. In the daytime the sun lights up the sky so brightly that stars are not seen. The blue color of the clear sky is due to the scattering of sunlight on countless numbers of extremely minute particles, the scattered light being seen against the darkness of outer space. The red and yellow colors near the horizon at sunrise and sunset are due to the sifting out of other colors as the sunlight passes obliquely through a great thickness of atmosphere.

As the sun sinks slowly below the western horizon after a clear sunset, a pink or rosy arch of sunlit air — the twilight arch — may be seen slowly rising over the

eastern horizon; the dull blue sky below the arch is darkened by the shadow of the earth. A similar arch and shadow may be seen sinking in the west before a clear sunrise. Thus the shadow of night may be seen following the sunlit air of one day and disappearing before the sunlight of the next.

24. Temperature of the Atmosphere. — The temperature of the land and sea surface and of the atmosphere is controlled by the rays of the sun. The temperature of the atmosphere is not much affected directly by the sun's rays, because the air is so transparent that the rays are very little taken in or absorbed by it; hence the upper air is everywhere cold. The temperature of the lower air is largely controlled by the temperature of the land or sea surface on which the air rests. The sea surface absorbs the sun's rays somewhat more actively, and the land surface much more actively, than the air does; thus they become warmer than the air. The air lying next to the heated surface is then warmed by heat that is carried or conducted from the land or sea to the air.

At night, when sunshine is absent, land, sea, and air cool by radiating their own heat (giving out rays) toward outer space. Just as the air absorbs the rays of the sun very imperfectly in the daytime, so it gives up very little of its own heat by radiating at night. The sea surface is somewhat more active than the air in cooling by radiation at night, and the land surface is much more so. Hence the lower air is cooled at night by conduction of its heat to the cooling surfaces on which it rests. In the upper air the diurnal

range or the change of temperature from day to night is very small; it is somewhat greater in the lower air on the oceans; it is much greater in the lower air on the lands.

The sun's rays fall almost vertically on every part of the earth's surface near the equator for several midday hours, and there high temperatures must prevail. The rays fall obliquely on the polar regions, so that each ray is there spread over a larger surface than in the torrid zone, and its noon effect is no greater than that of an early morning or afternoon ray near the equator; hence low temperatures must prevail around the poles. This may be illustrated by the difference in the heating effect of sunshine on the two slopes of a road that runs north and south over a hill. Between poles and equator intermediate temperatures are maintained.

High, medium, and low temperatures are thus distributed in belts — hot, medium, and cold — roughly parallel to the equator; the belts are known as the torrid, temperate, and frigid zones. Fortunately the cold or frigid areas occupy a relatively small part of the world.

Yet even in the torrid zone lofty mountains rise into air that is so cold that snow lies on their upper parts all the year round. The lower limit of the permanent snow fields is called the snow line. It is about three miles above sea level in the mid-torrid zone; about a mile above in latitude 55° or 60° N. or S.; it descends to sea level within the frigid zone, where permanent snow may be found even on the lowlands.

Heated air expands. Hence, volume for volume, hot air is lighter than cold air; the air of the torrid zone is

lighter than that of the frigid zones. This fact will be found of great importance as a cause of the winds.

25. Mirage. — A curious consequence of the strong control of air temperature by that of the land or sea surface on which the air rests is sometimes seen in the reflection of distant objects by the lower layer of air when its temperature is distinctly unlike that of the overlying air. A reflection of this kind is called a mirage (French, meaning "reflection"; pron. *meerahzh*). Its cause is as follows:

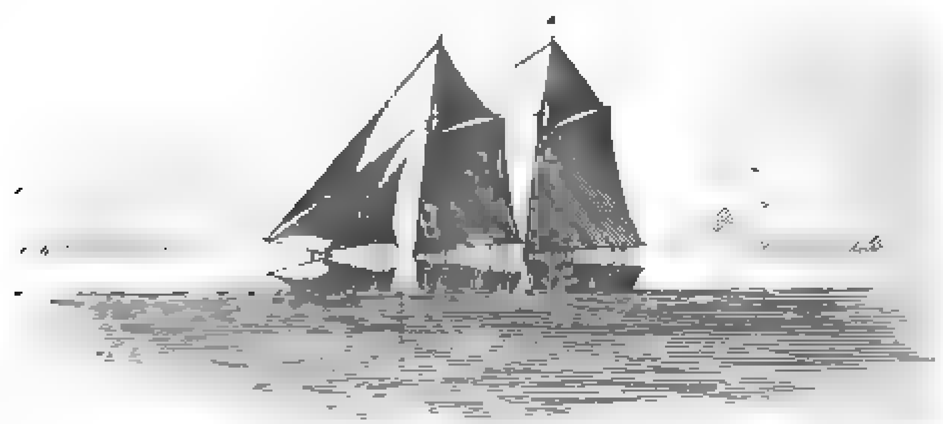

FIG. 9. Mirage of Part of a Schooner, formed on a Thin Layer of Air

The surface of a level desert in a warm zone becomes very hot under unclouded summer sunshine, and the air close to the ground is heated by conduction, so that it becomes much hotter than that three or four feet higher. The upper surface of the hot air acts like a mirror and gives an inverted reflection of objects beyond it. The reflecting air surface thus imitates a water surface so well that travelers are often deceived by it and think that a lake exists where in reality there is nothing but dry sand.

When cold air blows over a warmer sea its lower layer may be heated by conduction from the water, so as to become distinctly warmer than the air at a greater height. When warm air blows over a colder sea the lower part may be cooled by conduction. In either case the lower layer may reflect the figure of distant vessels, the reflected image being seen upside down beneath the object itself, if the lower layer of air is thin and the observer is above it; but above the object itself, if the lower layer is thicker and the observer is within it.

The equivalent of a mirage may often be seen by looking close along a brick wall that is exposed to strong sunshine in calm warm weather. Objects that are nearly in line with the wall may be seen reflected on the film of hot air next to it.

26. Thermometers. — The temperature of the air and of other bodies may be measured by the thermometer (temperature measure), consisting of a fine tube opening into a bulb at its lower end and containing mercury (or other liquid). The glass and the mercury take the temperature of the surrounding air. If warmed, both expand, but the liquid mercury expands more than the solid glass, and part of the mercury is therefore pushed from the bulb into the tube; if cooled, both contract and some of the mercury is withdrawn from the tube into the bulb. Thus the height of the mercury in the tube measures relative heat and cold, or temperature.

In the United States and Great Britain it is still customary to employ the Fahrenheit thermometer (F.),

marking 32° at the freezing point and 212° at the boiling point of water. In continental Europe the Centigrade thermometer (C.) is used, reading 0° at the freezing and 100° at the boiling point.

Some thermometers are arranged so as to give a continuous temperature record in a curve drawn on a sheet of paper; such instruments are called self-recording thermometers, or thermographs, one pattern being shown in Figure 10. Others are contrived so as to register the highest (maximum) and lowest (minimum) temperatures of the day; this is sometimes done by placing an index or short piece of fine wire inside the tube, so that it may be pushed up or down as the liquid expands or contracts. Such instruments are called maximum and minimum thermometers.

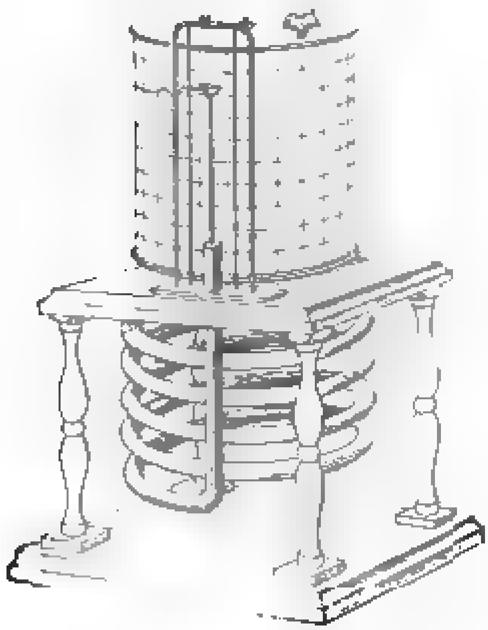

Fig. 10
The Comey Self-Recording Thermometer

When the thermometer is used to measure the temperature of the air it should be suspended so as to be protected from direct sunshine and from rain and snow, but exposed to the wind. If placed outside of a window, the thermometer should be on the north side of the building, free from the wall and where warm air escaping from windows cannot affect it. It is better placed in a special shelter, away from buildings and trees.

27. Temperature Charts and Mean Temperatures. — The distribution of temperature is indicated on charts by lines drawn through places having the same temperature.

Figure 11 gives the degrees of temperature prevailing over the middle and eastern United States on a certain morning. The dotted line is drawn so as to separate all places having higher temperatures (warmer) than 40° from those having lower temperatures (colder). Similar lines may be drawn for temperatures of 10°, 20°, 30°, 50°, and 60°. Each of these lines is called an isothermal (equal temperature) line, or isotherm. It is a line of uniform temperature, separating regions of higher and lower temperature.

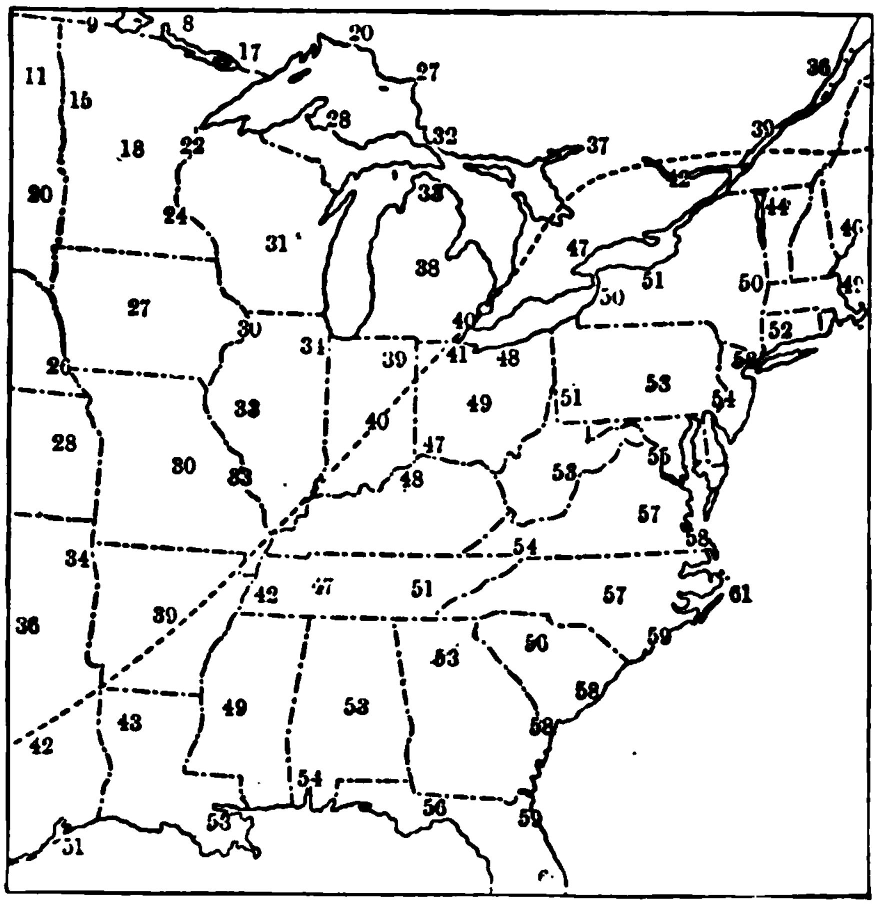

FIG. 11. Illustration of an Isothermal Line

In the example here given all the states northwest of a line drawn from the southwest corner of Arkansas to the western end of Lake Erie have temperatures lower than 40°. All the states southeast of this line have temperatures higher than 40°. Many illustrations of this kind are afforded by the daily weather maps issued by the national Weather Bureau. What would be

the temperature of a place halfway between the isotherms of 50° and 60°?

If records of temperature are kept at regular hours every day for a month, the hours being chosen so as to include the cooler as well as the warmer periods of the day, the sum of all the temperatures divided by the number of observations will give the average or mean

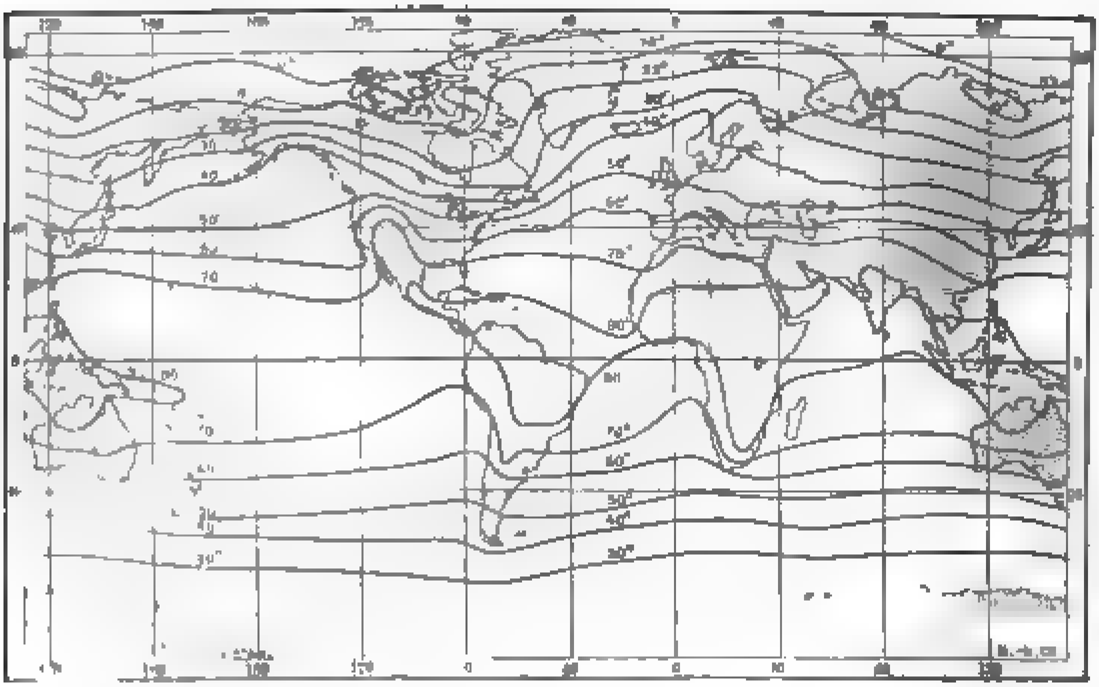

FIG. 12 Chart of Mean Annual Temperatures

temperature of the month. Similarly, if observations are kept up through a whole year, the mean temperature of the year may be determined. The mean temperatures of a place for a year usually differ by a small amount in successive years; hence the standard mean annual temperature of a place is determined by averaging the means of ten or twenty successive years. Observations of temperature have now been made during many years at a great

many places, so that the distribution of temperature all over the world, except in the two frigid zones, is fairly well known.

The distribution of mean annual temperatures for the year is shown by isotherms on the chart of the world, Figure 12, which is therefore called a chart of annual isotherms. A line drawn near the earth's equator, through the middle of the belt of greatest heat, is called the heat equator, the average temperature of which is about 80°. From the heat equator the temperature decreases toward each pole at the rate of about one degree of the Fahrenheit thermometer scale to a degree of latitude.

In the southern hemisphere the isotherms are nearly parallel to the latitude circles; this is because the oceans there are so little interrupted by land.

In the northern hemisphere the isotherms are much more irregular, because the oceans are here interrupted by broad continents, and the temperatures on lands and seas are often unlike in the same latitude.

Exercise. What parts of the lands and oceans have a mean annual temperature above 70°? above 80°? What is the general path of the isotherm of zero in the northern hemisphere? Estimate from the chart the mean annual temperature of your home; of London; of Cape of Good Hope.

28. Circulation of the Atmosphere. — Movements of the atmosphere are usually caused by differences of temperature. For example, a movement of air will take place between two rooms, one warm and the other cold, if a door is opened between them. The cold air is heavier than the warm air. Cold air will therefore creep into the lower

part of the warm room, while the light warm air spreads into the upper part of the cold room. The movement may be shown by the drift of smoke from a smoldering match. If the cold air is warmed as it enters the warm room, and the warm air is cooled as it enters the cold room, the movement will continue indefinitely, the air going round and round in a circuit. Such a movement is called a circulation. It is also called a convectional circulation, because heat and cold are conveyed by the movement that is excited by differences of temperature.

In the same way the cold air of the polar regions, being heavier than the warm air of the torrid zone, continually tends to creep under it, thus forming convectional air currents in the lower atmosphere, which we know as winds. The warm air, being slowly raised all around the equatorial belt, tends to overflow north and south toward the poles, forming convectional air currents at a great height in the atmosphere.

The lower winds approaching the equator where sunshine is strong are warmed; thus their air is expanded and made lighter, so that it is in turn slowly raised over the equatorial belt to form the overflow toward the poles. The upper currents, flowing toward the poles, where sunshine is weak, are slowly cooled; hence their air settles down to lower levels and forms the currents returning toward the equator. A permanent interchanging movement or circulation is thus established between the warmer and colder parts of the earth. It must continue as long as the sun warms the equatorial more than the polar regions. On account of the earth's rotation the air does not move

directly north and south, but is turned obliquely toward the east or west. (See page 85.)

Changes of temperature in the circulating atmosphere are produced not only during movements toward or from the equatorial belt, but also during the ascent or descent of the air currents. As the warm air rises the pressure of the overlying atmosphere upon it is less and less; the rising air therefore expands, and in so doing it is cooled; hence even over the torrid zone the upper atmosphere is cold. On the other hand, as the descending air in higher latitudes sinks to lower levels a greater and greater amount of air rests upon it; it is thus compressed and warmed. The descent of air from a great altitude is therefore not a cause of cold, for the air is warmed by compression as it comes down.

Changes of temperature of this kind will later be seen to be of importance in producing and in dissolving rain clouds. Illustrations of such changes may be found in a small way by noting the coolness of the air that expands as it flows out of a bicycle tire when the valve is opened, and the warmth of an air pump in which air has been compressed in order to force it into a tire.

The most general movements of the atmosphere thus established on a planet like the earth may be called the *planetary circulation;* the lower members of this circulation are the planetary winds. The surface winds move much slower than the upper currents, on account of friction with the earth's surface.

29. Observation of Winds. — The direction of the wind is determined by a vane or arrow, turning easily on a

vertical axis and freely exposed, as on a spire or high pole, to the movement of the air. The wind is named after the point of the compass from which it blows.

The strength of the wind may be described as light, moderate, strong (twenty miles an hour), fresh gale, whole gale, hurricane (seventy-five or more miles an hour); or it may be determined in miles per hour by an anemometer (wind measure) turning on a vertical axis, as in Figure 13.

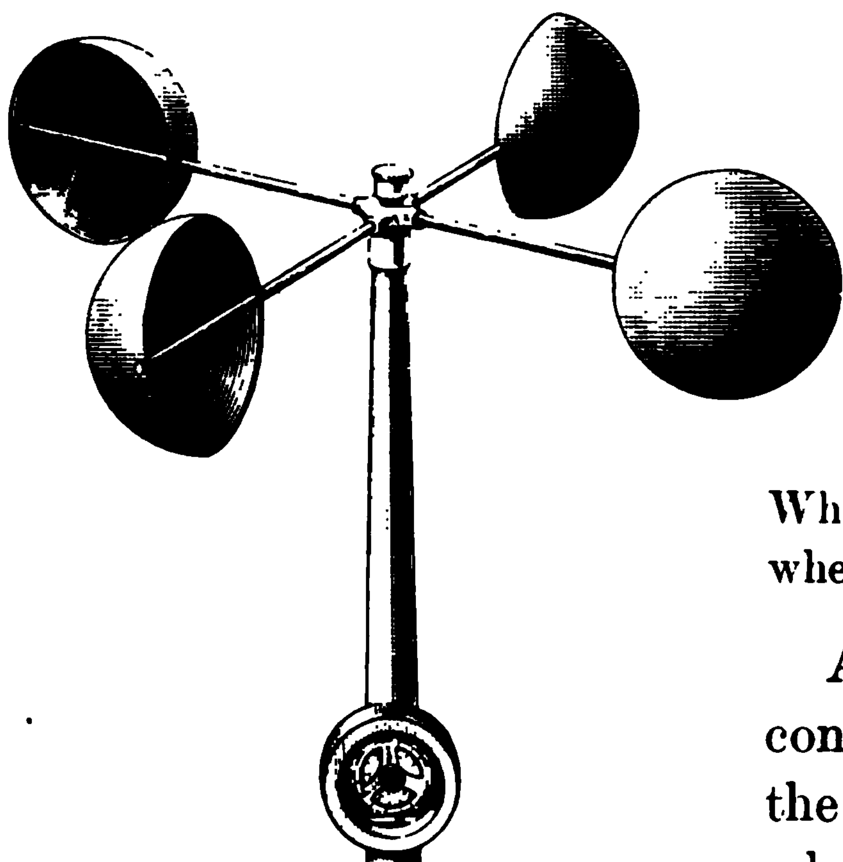

FIG. 13. Anemometer

Describe the arrangement of the cups on the arms of this instrument. Which way will the arms turn when the wind blows? Why?

A pointer on a small dial, connected with the axis of the turning arms by cog-wheels, indicates the movement of the wind in miles per hour.

The surface wind on the uneven lands seldom blows in straight lines with uniform velocity. It usually rolls and whirls, now faster, now slower.

30. Rainfall. — Water is evaporated from the ocean surface, especially from its warmer parts, and the invisible vapor thus formed mixes with the air and is carried about in the winds. When the moist air is sufficiently cooled

the vapor in it is condensed into minute water drops or snow crystals, and the air becomes cloudy. If the cooling continues still further, rain or snow may fall. The vapor may thus be returned directly to the oceans, or it may fall upon the lands, whence it returns to the oceans in streams and rivers. In this way there is a circulation of water through the atmosphere, from the ocean and back again.

The processes by which the air is cooled are nearly always connected with its movements. Hence the general distribution of rainfall will be referred to in the following account of the winds, while a fuller account of clouds, rain, and snow will be given farther on.

31. Planetary Winds. — The most important members of the planetary winds are the trade winds and the prevailing westerlies.

The trade winds blow with much regularity from about latitude 28° N. and S. obliquely toward a belt of low atmospheric pressure around the equator, from the northeast in the northern hemisphere, and from the southeast in the southern. The prevailing westerly winds blow from a westerly source, but usually with a slight inclination toward the pole, over the greater part of the temperate zones; they form great spiral whirls around regions of low pressure in the high latitudes of each hemisphere. These winds are made irregular by the occurrence of many smaller whirls, about 1000 miles in diameter, which drift eastward with the general movement of the atmosphere in middle latitudes. The winds of the polar regions are little known.

Narrow belts of light variable winds and frequent calms lie between the several belts of steadier winds; in these belts of light winds the pressure of the atmosphere is so nearly uniform that the air is not pushed steadily in any direction. All these members of the planetary circulation are better defined over the oceans than on the lands.

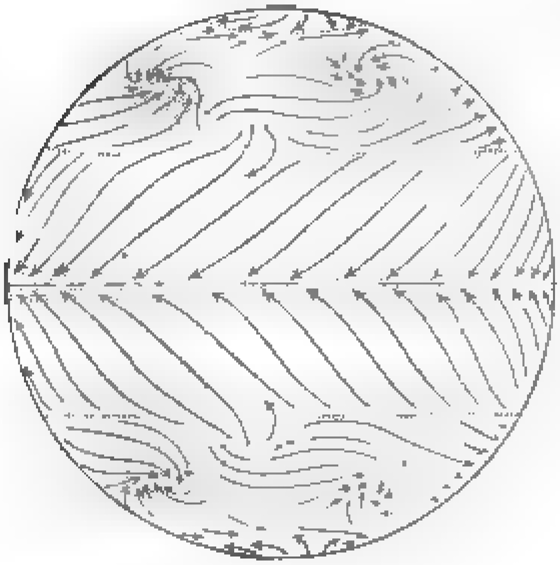

FIG. 14. The Planetary Circulation of the Atmosphere

Point out and name the several members of the planetary circulation in Figure 14. In what directions do their winds blow? Between what latitudes do they occur?

The *trade winds* are so called from the constancy with which they follow their course, the word *trade* formerly having meant "steady." They warm slowly as they approach the heat equator. Their velocity at sea is from ten to thirty miles an hour. They give fair weather, seldom interrupted by storms.

When sailing vessels enter the trade-wind belt they may count upon making good headway. If sailing with the winds, extra sails are often rigged out on the ends of the yards, and thus aided by a broadened stretch of canvas the vessels speed along day and night.

Coasts upon which the trade winds blow are usually beaten with heavy surf, so that landing is difficult, except in well-protected harbors. This is the case on the northeast side of the Windward islands in the Lesser Antilles.

Plate II. A Sailing Vessel at Sea

Lowlands over which the trade winds blow are made desert by the drying action of their warming air; for as the winds become warmer they take up any moisture that they find instead of giving up what they have. The African Sahara and the central Australian deserts are thus explained: it is entirely on account of their dryness and not because of the infertility of their soils that these regions are barren.

Where the trade winds encounter mountain ranges they are forced to ascend the side on which they approach (the windward side). As they rise the air expands and cools; as the air cools some of the invisible vapor that it contains is condensed into minute drops of water; thus the ascending air becomes cloudy and rainy. The eastern slope of the Andes, about the headwaters of the Amazon, the mountains along the east coast of Brazil under the southeast trades, and the eastern slopes of the highlands of Mexico and Central America under the northeast trades thus receive a good amount of rainfall (80 to 100 inches a year). All these mountain slopes bear heavy forests.

The further slope of the mountains, where the winds descend (the leeward side), is relatively dry and barren, because as the air descends it is compressed by the weight of the air that follows upon it; as it is compressed it is warmed, and as it warms it holds all the vapor that it has and eagerly takes up any vapor it can get from the ground over which it blows. This is especially noticeable on the western side of the Peruvian Andes, where much of the land is a desert in spite of being near the ocean.

Even in the Sahara the few mountains that interrupt

the general surface receive a sufficient rainfall to permit tree growth; but the streams supplied on the mountain sides wither away after descending to the desert below.

The *prevailing westerlies* are much less regular than the trades. They may weaken to less than ten miles an hour, or strengthen to gales of sixty or more miles an hour. They often shift from their general course to take part in the drifting spiral movements indicated in the temperate latitudes of Figure 14. It is chiefly to these great whirllike movements that the frequent changes of weather in temperate latitudes are due.

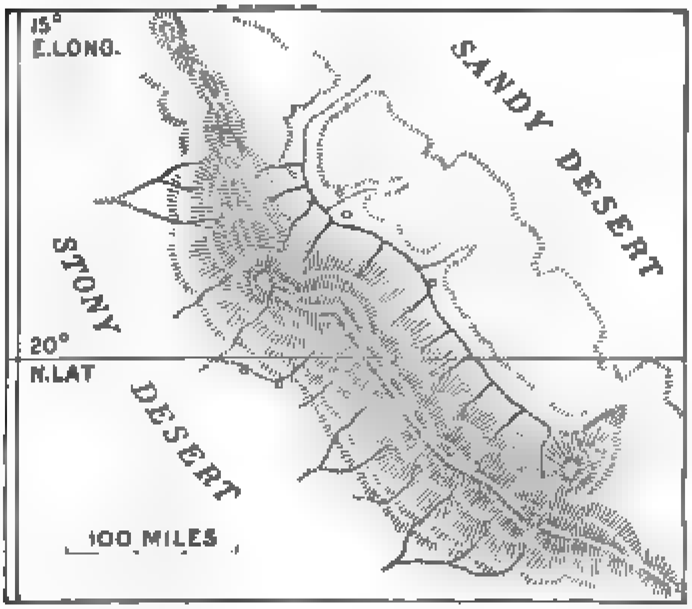

FIG. 15. Wet-Weather Streams of the Tarso Mountains, Sahara. Locate these mountains on the chart of mean annual temperatures, Figure 12, by the latitude and longitude here given

The area of the United States lies almost entirely within the belt of the prevailing westerlies. If the wind is observed at noon every day for a month or two, a westerly direction will be found more common than an easterly. If the drift of clouds is observed, the general movement of the atmospheric currents from the western toward the eastern side of the sky is very noticeable. Variations from these prevalent directions are generally due to the drifting spiral movements.

The lands under the westerly winds are generally well watered if they do not lie too far from the oceans ; the continental interiors are comparatively dry. Abundant rainfall is received on the mountainous Pacific slopes of North and South America in middle latitudes, but the opposite slopes are drier. In these latitudes the western (windward) slope of the mountains is heavily forested, while the eastern (leeward) slope has an open tree growth or none. The distribution of forests over the great American mountain system thus gives striking illustration of the relation of timber supply to winds, land forms, and rainfall.

The belt of calms and light breezes in the neighborhood of the equator, between the trade winds, is called the equatorial calm belt; that part of the belt which lies on the oceans is known to sailors as the *doldrums*. The air in the doldrums is moist and sultry, for the warm inflowing trade winds gather much water vapor as they blow over the ocean. The sky is prevailingly cloudy; rain falls every day or two, especially in the late afternoon or night. The lands are heavily forested under this warm and moist belt, and agriculture is difficult from the very luxuriance of vegetation.

Sailing vessels bound across the equator are frequently becalmed for several days in the doldrums; there they lie idle, rocking very gently to and fro in the long flat swell that sweeps across the glassy waters. They must then take advantage of every light breeze to push onward and reach the trade winds beyond. The dull sky, the sultry air, and the glassy sea make the delay all the more vexatious.

The rain of the doldrums results from the slow ascent of the warm moist air supplied by the inflowing trade winds. The lower air is raised to greater and greater height by the inflow of more air beneath from both sides; it expands as it rises, and cools as it expands; the vapor in the air is then condensed into cloud particles, the clouds become heavier and heavier and give forth plentiful rain; the air from which the rain has fallen continues to rise and at last overflows aloft and thus supplies the upper currents that move obliquely toward the poles. Violent thunderstorms are frequently formed in the great cloud masses of the calm belt.

The ill-defined belts of light breezes and occasional calms lying between the trades and the prevailing westerlies in each hemisphere are known as the *horse latitudes*. Their light winds usually blow obliquely outward on both sides; hence the air here must slowly descend from the upper currents to supply the outflowing breezes. As the air slowly settles down it is compressed by the weight of that which rolls in on top of it: as it is compressed it is warmed, and as it is warmed any clouds that it may have contained are dissolved; hence clear fair weather is prevalent in this belt.

32. Whirls of the Westerly Winds. — The irregular winds by which the prevailing westerlies are so often interrupted sometimes have an inward, sometimes an outward, spiraling movement, as in Figure 16. They are like great slow-turning whirls from 500 to 1000 miles in diameter: they may be compared to eddies in streams of water.

When blowing outward the air slowly descends from aloft; the winds are light and the weather is fair, for the reasons already given for the fair weather of the horse latitudes. When blowing inward the air slowly ascends, and the weather is cloudy and wet, for the reasons given in explaining the doldrums. Here the winds may gain a stormy strength, fifty to eighty miles an hour on land and sometimes over one hundred miles an hour at sea.

Exercise. Locate the centers of the two whirls shown in Figure 16. Describe the spiral movement of the winds with respect to the centers. In which whirl does the turning around the center agree with the turning of the hands of the clock? Which whirl should have low pressure? Which one fair weather?

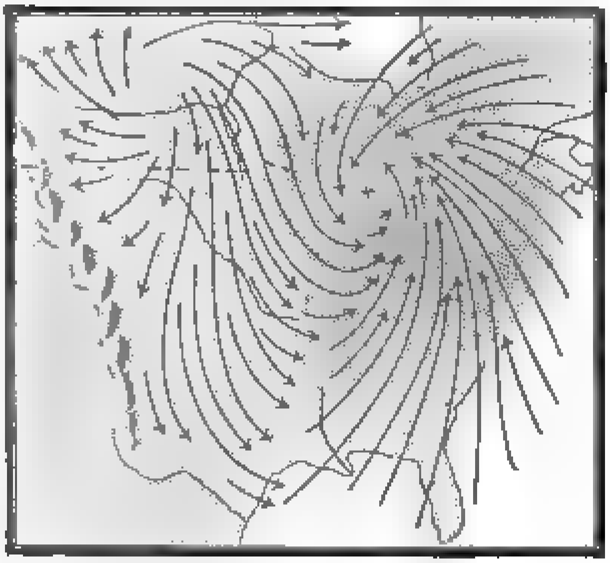

FIG. 16. Inward and Outward Whirls

Both classes of whirls travel from 500 to 1000 miles a day in an easterly direction, with the general drift of the atmosphere in temperate latitudes. Changes of weather are caused by their passage. The whirls may strengthen and increase in area for a time, then weaken and fade away; their duration being from a few days to two or three weeks, and their distance of travel from 5000 to 15,000 miles or more. The direction in which the whirls turn in the northern hemisphere is opposite to that in the southern; that is, the outflowing spirals turn clockwise in the northern hemisphere, as in

Figure 16, and counter-clockwise in the southern hemisphere. How do the inflowing spirals turn in the two hemispheres?

The pressure of the atmosphere, as shown by the barometer, is less than usual about the central part of the stormy inward whirls, and greater than usual in the fair-weather outward whirls. Hence they are often called low-pressure and high-pressure areas. They have also been named cyclonic and anticyclonic areas from the curving movement of their winds. They will be further described in the section on weather.

33. Seasons and Zones. — As the earth moves around the sun there are six months in each year (March 21 to September 22) in which the northern hemisphere is inclined somewhat toward the sun, so that it has longer days and stronger sunshine than the southern, which is at the same time inclined somewhat away from the sun, as in Figure 17.

In this condition the gain of heat in the northern hemisphere by the absorption of the strong sunshine during the long days is greater than the loss of heat by radiation during the short nights; hence the temperature there rises above the mean of the year. But in the southern hemisphere the loss of heat by radiation during the long nights is greater than the gain by absorption of weak sunshine during the short days; hence the temperature there falls below the mean of the year. During these months the northern may be called the summer hemisphere, and the southern the winter hemisphere.

During the other six months of the year (September 22 to March 21) the southern hemisphere is inclined toward the sun, and the northern away from it, so that the above

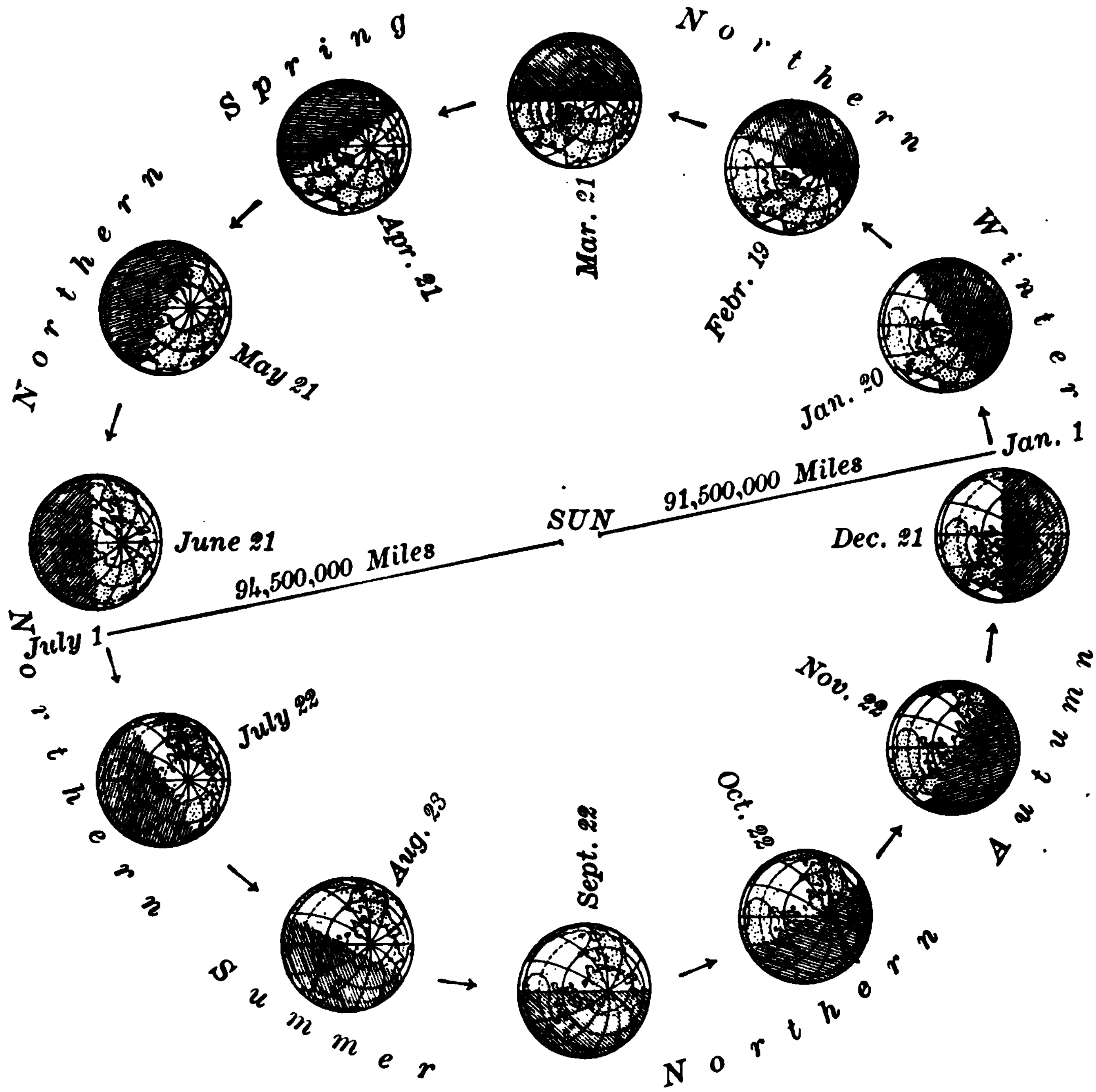

FIG. 17. Monthly Positions of the Earth with Respect to the Sun

conditions are reversed. The southern is then the summer hemisphere, and the northern the winter hemisphere.

In both hemispheres the succession of higher and lower temperatures during the year produces the change of

seasons. The winter months in the northern hemisphere are December, January, and February (these being the summer months of the southern hemisphere); the spring months are March, April, and May; the summer months, June, July, and August; the autumn or fall months, September, October, and November.

The zones may be defined by means of Figure 17 as follows: In the torrid zone, from $23\frac{1}{2}°$ N. to $23\frac{1}{2}°$ S., every point receives vertical sunshine sometime in the year; here the days do not vary much from twelve hours in length. In the frigid zone, extending $23\frac{1}{2}°$ from each pole, there is at least one day in the year when the sun does not rise and another when it does not set; here the days vary greatly in length. The temperate zones occupy the space between the torrid and the frigid zones ($23\frac{1}{2}°$ to $66\frac{1}{2}°$), north and south latitude; here no place has vertical sunshine on any day, and no day passes without a sunrise and a sunset.

If zones are limited by the mean annual isotherms of 70° and 30°, their borders are much more irregular than when limited by sunshine.

34. Observations of the Sun. — Records of thermometer readings during the school year should be used to show the general fall of temperature to midwinter, and the general rise from midwinter to midsummer. These changes of temperature should be connected with the changes in the apparent movement of the sun. In late December the sun rises south of east and sets south of west; at midday it reaches but a moderate altitude above

the southern horizon; at this time the duration of daylight is less than twelve hours and the strength of the sunshine is reduced. In late June these conditions are all reversed. The low temperature of winter is thus seen to depend on the weak sunshine of short days, and the high temperature of summer on the strong sunshine of long days. The rising temperature through spring results from the strengthening of sunshine in the lengthening days; the falling temperature of autumn, from the weakening sunshine in the shortening days. (See Supplement.)

35. Change of Temperature with the Seasons. — An observer at any one place notes the familiar succession of the seasons during the course of the year. A better understanding of the meaning of the seasons may be gained if the earth as a whole is considered, as on the above charts. It is then seen that for a time the heat equator moves a moderate distance from the geographic equator into the summer hemisphere, while the high temperatures of the torrid zone advance into the temperate zone, and the rigor of polar cold is somewhat lessened; in the other hemisphere the polar cold is extreme, low temperatures advance over the temperate zone, and the heat on the border of the torrid zone is decreased.

In the next half year the heat equator moves slowly back and crosses the geographic equator, and all these conditions are reversed. The year, or period in which the earth revolves around the sun and in which the change of seasons therefore take place, thus comes to be a natural measure of time.

36. January and July Isotherms. — The general distribution of mean temperatures for January and for July is shown in charts of monthly isotherms, Figures 18 and 19, on which the following exercise may be based.

Exercise. In which summer hemisphere does the heat equator stand farther from the geographic equator? Does the heat equator stand farther from the geographic equator on the oceans or on the lands? Where do midsummer temperatures of more than 90° occur? In which hemisphere do they cover the largest area? What is the lowest mean temperature in January? Where does it occur?

About how much difference is there between January and July temperatures in latitude 40° S.? Where in latitude 40° N. is there a strong difference between January and July temperatures?

37. Mean Annual Range of Temperature. — The average change of temperature with the seasons may be best studied by taking the difference between the mean temperatures of January and July. This difference is called the mean annual range of temperature. It is shown for the different parts of the world in Figure 20. The range is generally less than 10° over the torrid oceans and less than 20° over most of the temperate oceans. On land the range increases. Places in the interior of continents have a much stronger range than those on continental borders or islands.

Central Australia and the interior of the Sahara have a range of over 30°. Over most of the United States the range is from 30° to 60°. Over a belt of land from Hudson bay into Alaska the range is more than 80°. Over the greater part of Europe-Asia the range exceeds 40°.

In regions of the greatest range the winters are so cold that the ground is frozen to a depth of 100 feet or more.

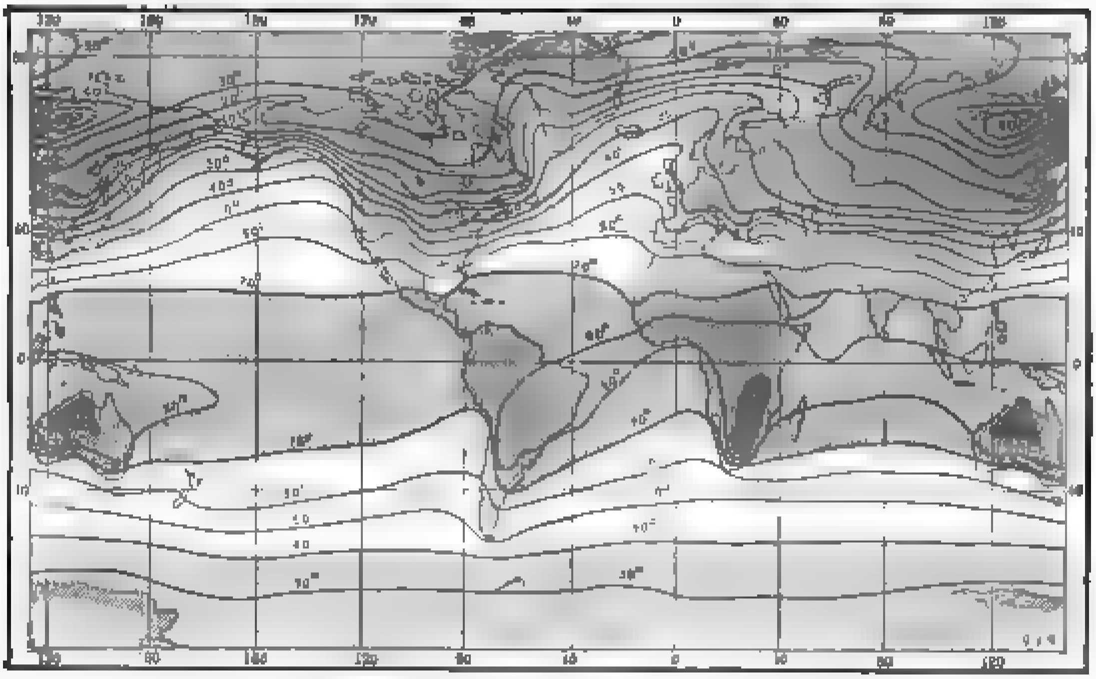

Fig. 18. Chart of Mean Temperatures for January

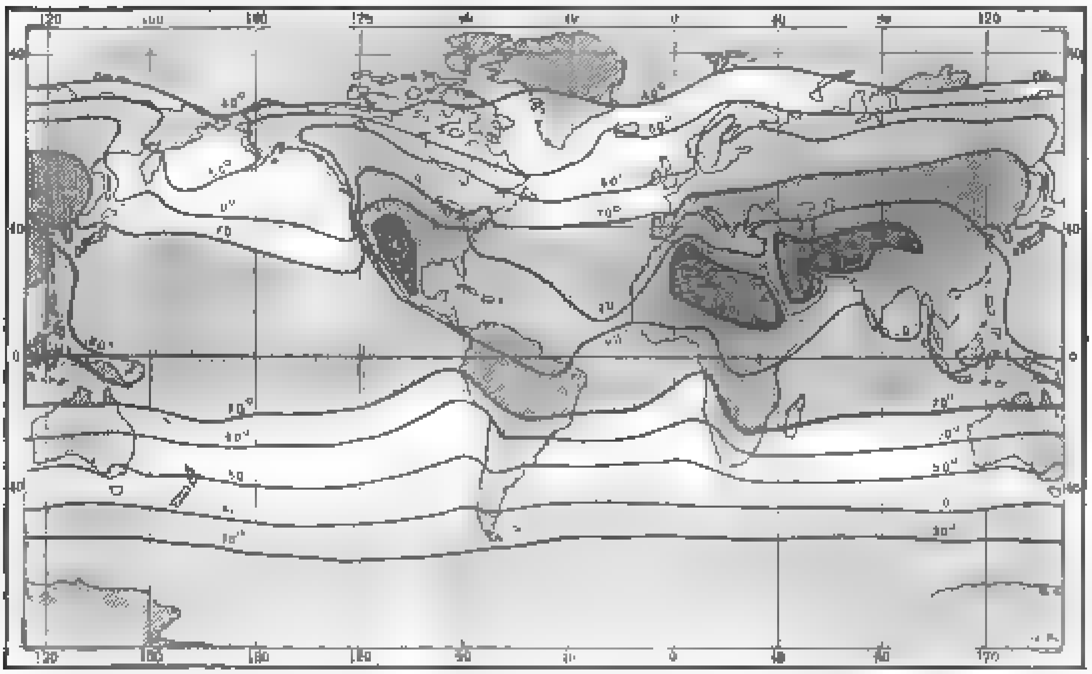

Fig. 19. Chart of Mean Temperatures for July

In winter ice is so hard that the runner of a skate does not hold upon it; wood is too hard to be chopped with an ax. In summer thawing reaches only a few feet below the surface. Trees gain only a stunted growth or are altogether wanting.

Compare the annual range on the western and eastern coasts of the continents in temperate latitudes. On which

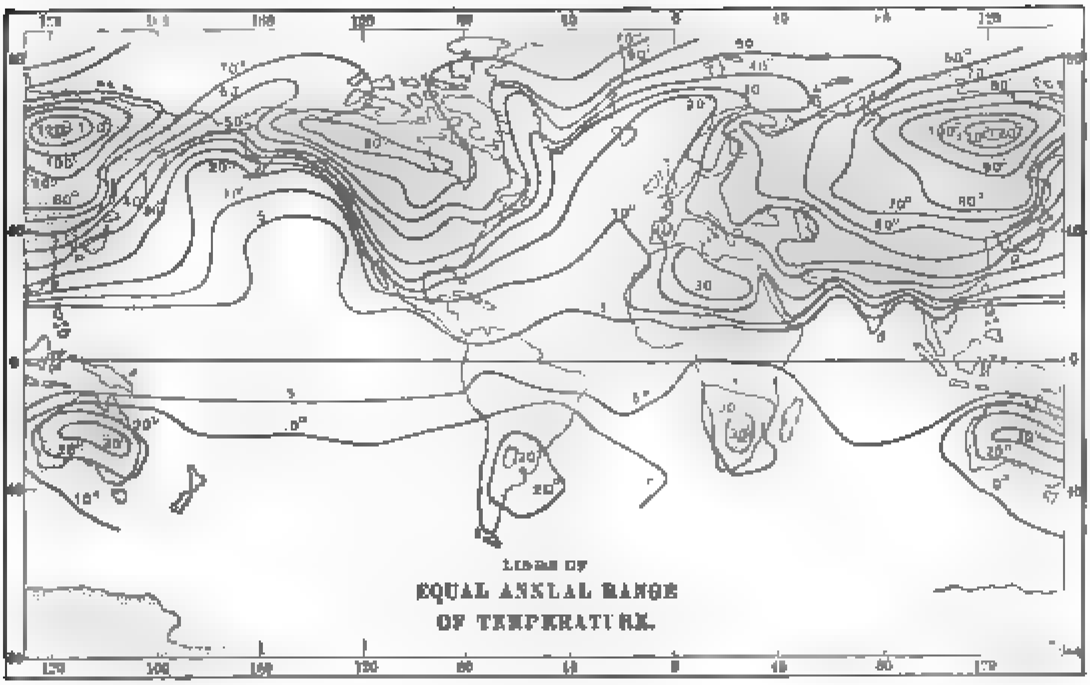

FIG 20. Chart of Annual Range of Temperature

coast is the range of less amount? The difference of range is due to the prevailing westerly winds, which carry the nearly uniform conditions of the ocean on to the western coasts, and the changing conditions of the continental interior out to the eastern coast.

Exercise. Where is the greatest annual range? What is its amount? Compare the annual range of Labrador and England, of Virginia and Spain, of Japan and California.

The annual changes of temperature are much more distinct in the northern hemisphere, where there is much land, than in the southern, where there is much ocean. This is because the land surface changes its temperature more easily than the ocean surface, and therefore the air over the land becomes hot in summer and cold in winter. The change of seasons in the north temperate zone, especially on the lands, is much stronger than in the south temperate zone. This is because the northern continents are broad in temperate latitudes, while the southern are relatively narrow.

Exercise. In Figure 20 follow the latitude circle of 40° or 50° N. around the earth. For how many degrees of longitude does it lie on the continents? How many on the oceans? Do the same for latitudes 40° or 50° S. Compare the results.

Winter and summer are not very different over the great oceans of the south temperate zones, where the weather is rather uniformly chill and damp, or inclement, all the year round. This is because water is slow to change its temperature; the ocean waters and the air over them suffer small changes of temperature during the year.

In the temperate zone the summer half year is the time of plant growth, and is therefore the season of greater activity in all industries immediately connected with agriculture. One of the most interesting consequences of the advance of spring and summer temperatures into higher latitudes is the northward passage of migratory birds, familiar to every lover of outdoor nature. The approach of winter is accompanied by the return of the birds to warmer latitudes.

38. Terrestrial Winds. — The strength of the planetary circulation and the boundaries of its wind belts vary with the seasons. Thus modified, the winds may be called terrestrial, as belonging to the earth in particular with its winters and summers, instead of to the other planets which may not have seasons like ours.

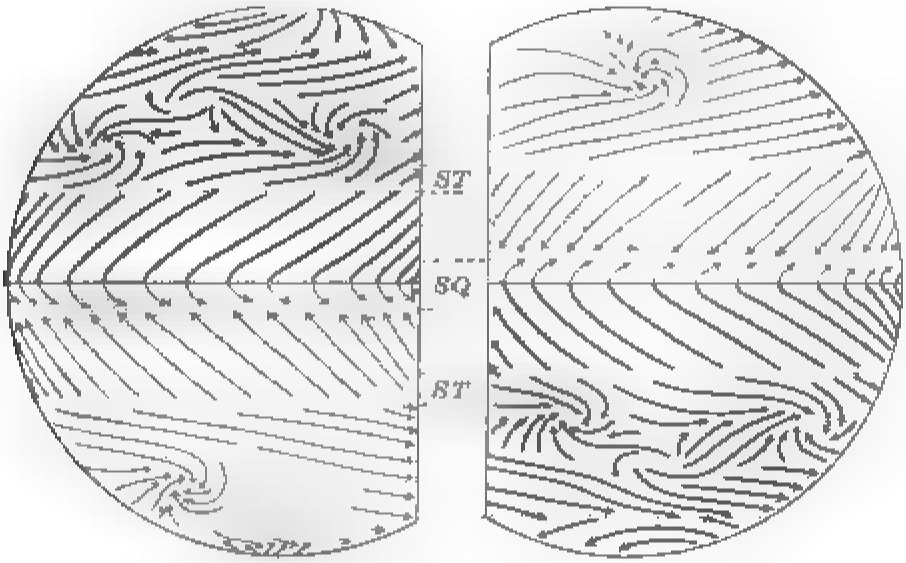

Fig. 21. Diagrams of Terrestrial Winds for January and July

Figure 21 gives a general scheme of the winds for January and July, without considering the irregular winds produced by the continents and their mountain ranges. The heavier lines show the stronger winds. In which month are the winds strongest in the northern hemisphere? In what season is this? Answer the same questions for the summer hemisphere. In what season are the prevailing westerlies most interrupted by spiraling winds (cyclones and anticyclones)?

Examine the isotherms in the northern hemisphere for January and July, Figures 18 and 19. In which month are the lines closer together? How can you tell from this in which month there is the greatest difference of temperature between the torrid zone and the Arctic regions? In which month would you expect the general

circulation in the northern hemisphere to be the stronger? Why? Answer the same questions for the southern hemisphere. Compare the results for the two hemispheres.

It is thus seen that in winter the difference of temperature between the equator and high latitudes is strengthened. As the general circulation of the atmosphere depends on this difference, the winds will generally be

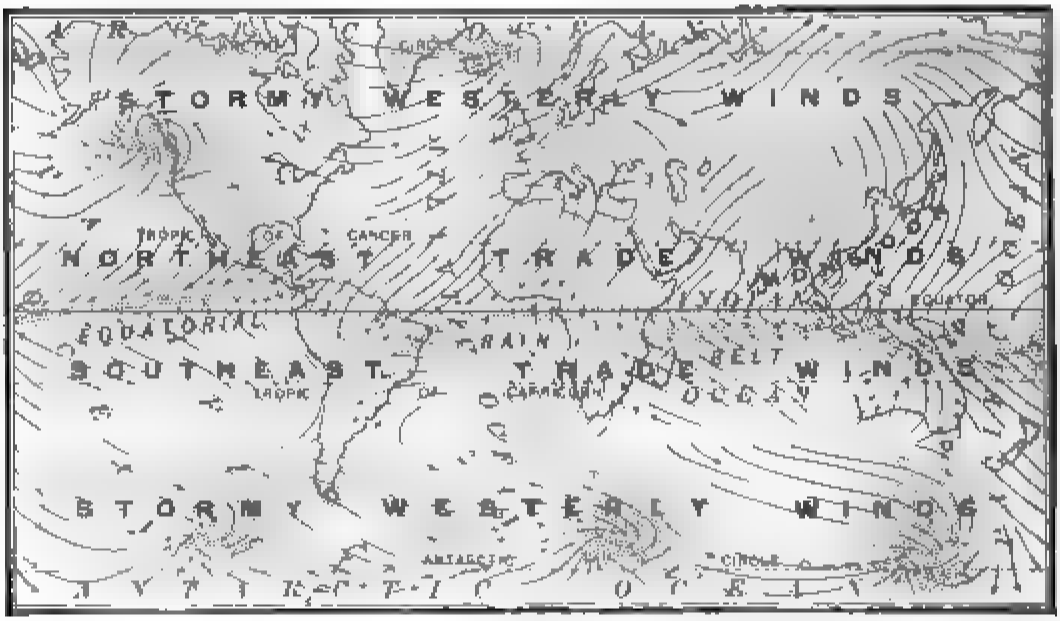

Fig. 22. Winds of January

stronger in winter than in summer. This is especially true of the prevailing westerlies and their spiraling cyclonic winds in the northern hemisphere; they frequently become stormy in winter, while they are relatively light in summer. In the southern hemisphere these changes are less marked. Why so?

Examine in Figure 21 the belts of light breezes and occasional calms between the trades and the westerlies. What is the name of these belts? Compare their positions in January and July. What

is the name of the belt of calms and light breezes between the trade winds? How does its position change with the seasons?

The horse latitudes and equatorial calms are much less regular in reality than they are represented in Figure 21, on account of the irregular outline and form of the lands. A better illustration of the prevailing winds for January and for July is given in Figures 22 and 23.

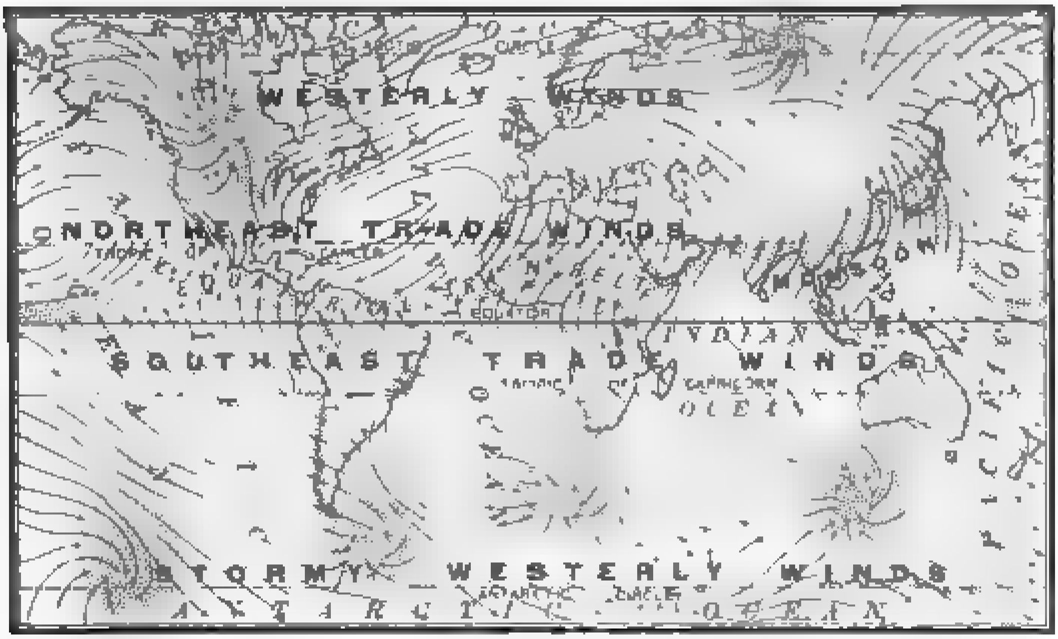

FIG. 23. Winds of July

The light and irregular winds of the horse latitudes migrate toward the equator in the winter of their hemisphere, and toward the pole in the summer; these belts of migration are known as the northern and southern subtropical belts (*ST*, Figure 21). Any country over which a subtropical belt is stretched will have the westerlies and their rainy storms in winter and the drying trades in summer. This is the case with southern California and the Mediterranean countries of southern Europe and northern Africa, as

well as with central Chile, southern Africa, and southern Australia. These countries are said to have a subtropical climate. In what months will they have their rainy season?

As countries in the subtropical belts are dry in the growing season, agriculture there generally requires the aid of irrigation (watering the fields by canals led from streams or reservoirs).

Like the calms of the horse latitudes, the calms and rains of the doldrums also migrate north and south during the year. The belt of winds and rainfall thus controlled forms the subequatorial belt (*SQ*, Figure 21). The migration of these three belts follows the migration of the sun.

The plains of the Orinoco in Venezuela, north of the equator, receive a plentiful rainfall in July and August, but in December and January they are relatively dry. In the wet season cattle find abundant pasture on the plains, but in the dry season they are driven into the valleys. On the plains between the headwaters of the Amazon and the Parana, south of the equator, the months of wet and dry seasons are reversed from those of Venezuela.

The western Sahara, between the reach of the subtropical (winter) rains on the north and the subequatorial (summer) rains on the south, gives no important river to the Atlantic along a thousand miles of coast line. The rise of the Nile in Egypt from June to September results from the northward advance of the equatorial rains over the upper part of this river basin, as in Figure 23.

39. Monsoons. — In the belt over which the equatorial calms move north and south during the year the trade winds change their direction in the warmer and cooler half years. Winds of this kind are called monsoons.

How do the winds blow in the northern half of the subequatorial belt (*SQ*, Figure 21) in January? in July? how in the southern half?

What parts of the equator are crossed by the extended northeast trades in January, Figure 22? by the extended southeast trades in July, Figure 23? Where do these extended winds cover the greatest area?

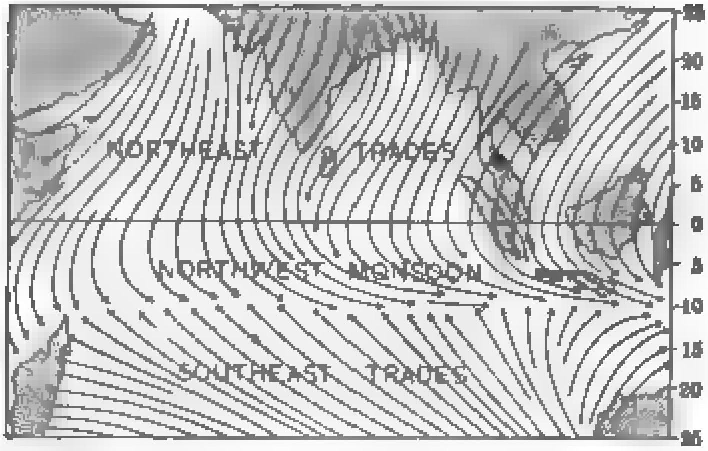

FIG. 24. January Monsoons in Indian Ocean

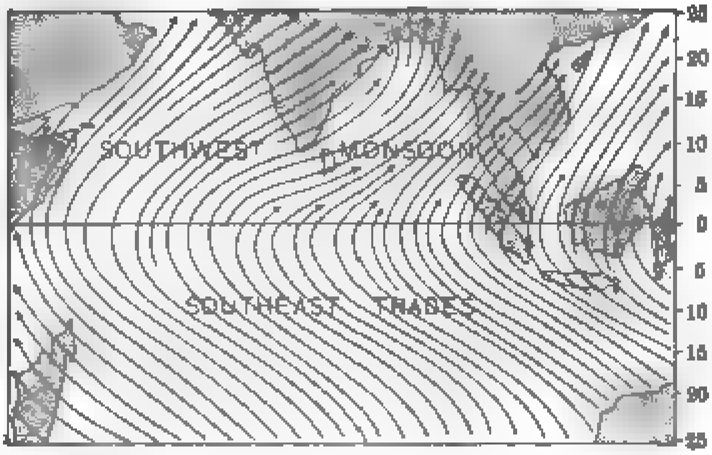

FIG. 25. July Monsoons in Indian Ocean

Note in Figure 24 the change in the direction of the northeast trades in January as they cross the geographical equator and enter the southern hemisphere on their way to the calm belt. What is the direction of the wind in the same part of the southern hemisphere in July? Note the corresponding change in the extended southeast trades for July in Figure 25.

The reason for this change of direction as the winds cross the equator is found in the earth's rotation, on account of

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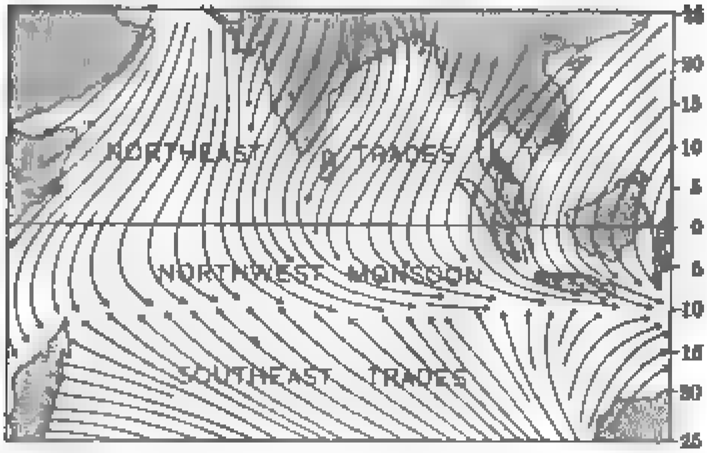

FIG. 24. January Monsoons in Indian Ocean

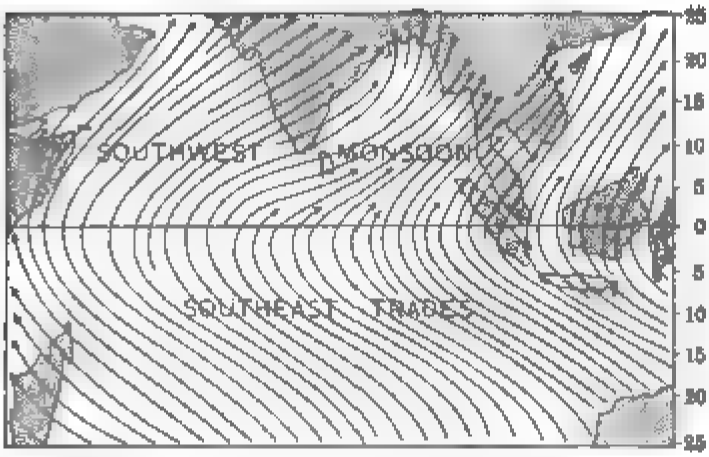

FIG. 25. July Monsoons in Indian Ocean

The reason for this change of direction as the winds cross the equator is found in the earth's rotation, on account of

which all winds in the northern hemisphere tend to turn to the right, and in the southern hemisphere to the left. On account of the irregular distribution of land and water monsoons are not evenly developed all around the equator.

The monsoons of the Indian ocean are the most remarkable of the world. In January a belt of northwest monsoon winds is developed for about ten degrees south of the equator, as in Figure 24. In July, when the heat equator has shifted far northward to the border of Asia, a broader belt of southwest monsoon winds is developed north of the equator, as in Figure 25.

The primitive sailing vessels of the Indian ocean in earlier centuries, poorly adapted for sailing against the wind, made voyages only as the monsoons favored their courses, going outward from India to Africa in one half year and returning in the next.

The east coast of the Malay peninsula is beaten by heavy surf under the northeast monsoon, and then the native fishermen stay ashore. But under the southwest monsoon, an offshore wind, the water is comparatively smooth, and large fleets of fishing boats put out to sea with their palm-leaf sails.

In what months would the events described in the two preceding paragraphs be expected?

40. Winds of the Continents. — As the air over the continents is warmer than that over the neighboring oceans in summer and colder in winter, the winds tend to blow inward toward continental centers in summer and outward from them in winter.

In the north temperate zone the cold land winds of winter tend outward toward the sea, and the far inland regions have much clear and dry weather. In summer the warm and moist sea winds tend inward toward the still warmer lands, and the interior parts of the large continents then have a greater abundance of clouds and rain.

The general circulation of the atmosphere is much complicated by this outward and inward tendency of the winds over the continents, as may be seen by comparing the winds of January and July over Asia, Figures 22 and 23, with the winds of corresponding latitudes in Figure 21. The regular belts of winds in the latter figure are much broken up, especially in the northern hemisphere.

41. Winds on Land. — The lower winds are generally not so strong or so regular on the uneven lands as on the level seas, although the upper currents over the lands still flow rapidly. In valleys the winds are much influenced by the direction of the inclosing slopes. Hence observers living in deep valleys may often determine the general direction of the winds better by watching the drift of the clouds than by noting the position of their wind vanes.

The air over the lands is cooler and therefore heavier than that over the sea at night, but warmer and lighter by day. Hence around the border of the lands the wind tends to blow alternately offshore at night and onshore by day for a short distance from the coast, such winds being known as land and sea breezes.

On the coasts in the torrid zone the sea breeze is welcome, as it tempers the excessive heat of the day on land.

The same is true of summer weather in the temperate zone. On the coast of Peru the fishermen sail offshore in the early morning with the land breeze, and return in the afternoon with the sea breeze.

42. Daytime Winds. — In fair, warm weather the lower air lying on the land becomes unduly heated by day, as compared with the overlying air. The warmer lower air then rises and the cooler upper air descends, this being a small example of convectional circulation. It is like the movement of water in a kettle that is heated at the bottom.

The faster-moving currents from aloft are thus brought down to the surface. Hence on lands the winds of fair weather in the daytime are commonly stronger than those of the night. This is prevailingly the case through the year on torrid lands; on the temperate lands it is common during summer weather, but is less noticed in winter. Why does no such daily change in the strength of the wind occur at sea?

43. Humidity. — The condition of the atmosphere as to the water vapor that it contains is expressed by the term *humidity.* When the air contains much vapor and feels damp the humidity is said to be high. When it contains little vapor and feels dry the humidity is low. The higher the temperature of the air, the greater the amount of vapor it may contain. When as much vapor is present as is possible at a given temperature the air is said to be in the state of saturation. The lower air over the ocean is usually almost saturated; in the doldrums the humidity

is always high. Far inland, in the desert regions of continents, the air may contain very little vapor; here the humidity is low. Dry air is more agreeable than damp, because it allows active evaporation from the skin. Cold damp air is chilly and "penetrating." Warm damp air is sultry and "close."

44. Dew and Frost. — Dew is a deposit of moisture on the ground, or on loose objects like leaves and sticks lying on the ground. It is formed when the ground is cooled at night by radiation; then the air near it is chilled by conduction, and some of the water vapor in the air is changed to the liquid form. The temperature at which dew begins to be formed in cooling air is called the *dew-point.*

Exercise. The dew-point may be determined by experiment as follows: Half fill a tin cup with water whose temperature is about like that of the air. Then slowly pour in ice water, stirring it with a thermometer. As the cup is cooled the air next to it is cooled also. As the air is cooled the vapor that it contains will more and more nearly saturate it. When the outer surface of the cup is first clouded by a deposit of moisture the air next to it has just passed the condition of saturation, and the temperature of the water gives a close indication of the dew-point. If ice is added so as to make the water still colder, more and more vapor will be condensed on the cup, the air constantly being saturated with the vapor that remains in it as its temperature falls.

When moisture is condensed upon the ground at temperatures below the freezing point it forms frost. Thus frost on the ground corresponds to snow in the air, and dew corresponds to rain.

Dew and frost are in part supplied from water vapor in the air that lies near the ground, in part by vapor that rises through the soil from its deeper and moister parts. In the daytime the vapor from the soil escapes into the warm air; but at night, when the ground is colder at the surface than beneath, the rising vapor is condensed.[1] Dewdrops found on the blades of grass and on the living leaves of plants close to the ground are in large part supplied by the water that the plants bring up from the ground through the roots. In the daytime the moisture evaporates from the leaves, but at night it may collect upon them in drops.

At night, when the air is calm and clear, the ground is cooled by losing its heat to cold outer space; the quiet lower air is then chilled, because it lies on the cooled ground, and dew (or frost) is formed. When the wind is blowing the lower air is constantly changed and none of it is much chilled; when the sky is cloudy at night the ground cools but little; hence on windy or cloudy nights little or no dew (or frost) is formed.

45. Clouds, Fog, and Mist. — The different processes by which water vapor is condensed[1] in the atmosphere produce clouds of many different forms. It has been explained that in daytime of fair summer weather the lower air tends to rise in convectional currents. The ascending air currents

[1] It should be noticed that the term *condensation*, when applied to vapor, refers to its change from the gaseous to the liquid (or solid) state, and not to its compression, as vapor, into a smaller volume. Hence condensation of vapor may take place while the air with which it is mixed is expanding, provided that the expansion produces sufficient cooling to lower the temperature below the dew-point.

PLATE III B. Cirrus Clouds

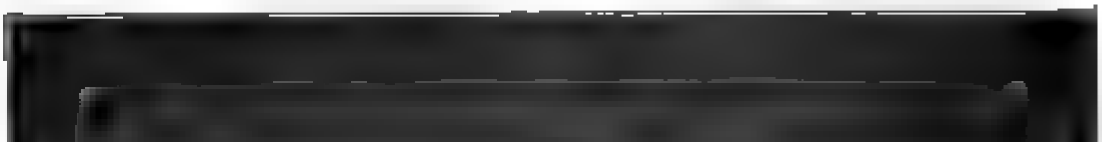

PLATE III A. Cumulus Clouds

expand and cool as they rise, and, if their ascent is great enough, some of their vapor is condensed, forming round-topped clouds, brilliant white in strong sunshine, as in Plate III, *A*; the air within the clouds is all saturated by the vapor it still contains. The clouds are of unequal size, but have their bases at about the same height (commonly one fourth to one half of a mile), and all drift along with the speed of the currents in which they are formed. Their rapid motion can be recognized by watching their shadows pass across a field; they nearly always drift eastward in the United States, being borne in the prevailing westerly winds of middle latitudes.

Clouds of this kind are called *cumulus* (heap) clouds. They usually begin to form in the warming morning hours of fair weather, but dissolve and disappear in the late afternoon, when sunshine weakens, the ground cools, and convection ceases.

It is usually the case that the great cyclonic storms of the westerly winds are preceded by long filmy or feathery strips of pale whitish cloud, as in Plate III, *B*. Clouds of this kind are formed at a height of several miles, in the air currents that flow out and forward from the upper part of the storm. They are called *cirrus* (curl) clouds. They consist of minute ice crystals, because the moisture forming them has been condensed in the cold upper air at temperatures below the freezing point. Sometimes the cirrus is spread out in a thin sheet called *cirro-stratus*. When the sun or moon is seen through a cirro-stratus a large ring faintly colored with red on the inside is seen around the luminary. Such a ring is called a halo; it is formed by

the bending (refraction) of the light in passing through the ice crystals. Halos are common and brilliant in the polar regions.

In the central parts of the great whirling cyclonic storms heavy dull-gray cloud sheets of great size are formed at a moderate height above the earth's surface by the gradual cooling of the inflowing winds. Clouds of this kind, from which rain or snow falls, are called *alto-nimbus* and *nimbus*. A nimbus cloud is shown on the right side of Plate IV. As with other clouds, the air within the nimbus is constantly saturated. These clouds often cover the area of several states at once, and they may hide the sun and stars for several days at a time, yielding plentiful rain or snow before they drift away eastward and reveal the clear sky again in fair weather. They are especially large and heavy in winter, when the westerly winds and their storms are strongest. When the sun or moon is seen through the fragments of nimbus clouds it is often closely surrounded by a brilliant glow, called a corona.

When a cloud is formed at so low a level that it rests on the ground or on the sea surface it is called fog. This is often the case when moist sea winds of mild temperature blow across a colder part of the sea or blow inland over snow-covered hills. Fog is often formed in valleys among mountains by the cooling of the lower air at night. Fog of this kind usually disappears in the morning sunshine, but if very heavy it may not be dissolved by the short and weak sunshine of a winter day.

A slight cooling of damp air may produce a faint cloudiness, known as mist, much less dense than fog.

46. Thunderstorms. — When the lower air is warm and moist it is apt to rise and form great cumulus clouds from ten to fifty miles in length, whose tops may reach heights of more than a mile. When the rising movement is active and the cloud grows to great size it may often be seen to spread out at the top in a cirro-stratus film, and about the same time rain falls from its base. If the rain becomes heavy, lightning flashes occur, causing peals of thunder; hence such storms are called thunderstorms.

Storms of this kind are common in the cloudy belt of the doldrums, where they usually occur in the afternoon

FIG. 26. A Distant Thunderstorm

and evening. They are also common on the lands in periods of hot summer weather. Much of the summer rain in the Mississippi valley falls from thunderstorms which drift eastward in the afternoon and night at a rate of twenty or thirty miles an hour, giving heavy rainfall for an hour or two as they pass by. A violent blast of wind, or thunder squall, often rushes forward from beneath the front of the cloud mass, raising a cloud of dust before the rain arrives.

During the growth of a thunderstorm cloud the water particles in it become charged with electricity. When the drops become large enough to fall as rain the electricity is discharged from one part of the cloud to another, or from

the cloud to the ground, in a great electric spark, or lightning flash. Thunder is the sound caused by the violent agitation of the air along the flash. It may be compared to the sound caused by snapping a whip. As sound travels through the air at the rate of a mile in five seconds, the distance of a flash can be determined in miles by counting the number of seconds between the lightning and its thunder clap and dividing the number by five. The "rolling" of thunder is caused partly by the continuous arrival of the sound from different parts of a long flash, partly by the echoing from clouds or from hills and mountains. At night the upper clouds of distant thunderstorms are illuminated by flashes, commonly called heat lightning, too far away for the thunder to be heard.

An unusually heavy and violent rain, popularly known as a cloud-burst, sometimes falls during a thunderstorm upon a small district. If on a hillside it may wash away the soil, baring the rock beneath.

47. The Rainbow. — When a thunderstorm passes eastward in the late afternoon a rainbow is usually seen by observers on the west of it. The bow is formed by the sunlight that is turned back and bent (refracted) by the drops that are falling from the rear of the cloud. The center of the bow will be directly opposite the sun. Why will a rainbow form a half circle at sunset? Why does a rainbow usually show less than a half circle? A bow forming a complete circle might be seen from a balloon.

48. Tornadoes and Waterspouts. — Violent whirlwinds are occasionally formed in thunderstorms. They are seldom

PLATE IV. Waterspout over Vineyard Sound, Aug. 19, 1896

more than a quarter of a mile in diameter; they drift along with the thunderstorm in which they are formed, usually in an easterly direction, passing by in a minute or two. Their whirling winds are strong enough to blow down trees and overturn buildings. Violent local storms of this kind are often called cyclones, or prairie twisters, in the Mississippi valley, but the name *tornado* is to be preferred in order to distinguish them from the much larger and less violent cyclonic storms.

When violent whirlwinds of this kind occur over a water surface a watery column is formed in their vortex; they are then called waterspouts. Plate IV shows a waterspout over Vineyard sound, southeastern Massachusetts, as photographed on Aug. 19, 1896. A vessel overtaken by such a whirlwind may be suddenly dismasted.

49. Tropical Cyclones (Hurricanes and Typhoons). — Violent storms known as tropical cyclones are occasionally developed in the doldrums when the heat equator stands farthest from the geographical equator. They appear to be, like thunderstorms, due to the inflow, ascent, and outflow of very warm moist air. They grow to be several hundred miles in diameter, with violent winds, whirling in great spirals around a center of low barometric pressure, great cloud sheets, and heavy rains.

As in the cyclonic storms of temperate latitudes, the winds of tropical cyclones turn counter-clockwise in the northern and clockwise in the southern hemisphere. As tropical cyclones increase in size, they travel slowly (one or two hundred miles a day) westward and toward the

temperate zone near the western border of their ocean. In a week or ten days they pass from the trade-wind belt into the prevailing westerlies. As they enter the temperate zone, still increasing in size but usually decreasing in violence, their path curves eastward, and they join the great procession of cyclonic storms of middle and higher

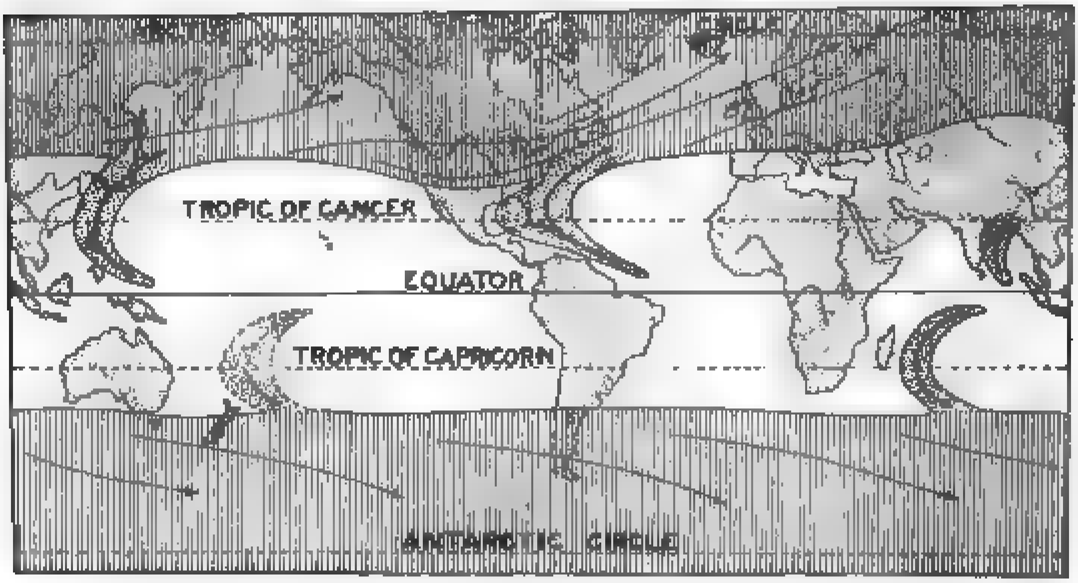

FIG. 27. Regions of Tropical Cyclones

latitudes. The chief regions of these storms are shown by dotted areas in Figure 27.

In the southern hemisphere the doldrums of the Atlantic hardly pass south of the equator, on account of the large supply of cooled water that comes northward west of Africa; hence no tropical cyclones occur on the Brazilian coast. In the western Pacific ocean the doldrums are farthest south in February and March, and at that time cyclones occur in the region of the Fiji islands. In the southern Indian ocean cyclones occur in the same months east of Madagascar.

In the northern hemisphere the doldrums are farthest north in the western Atlantic and Pacific in August and September; cyclones occur in these months in the West Indies, where they are commonly called hurricanes, and in the region of the Philippines, where they are known as typhoons. In the Indian ocean there are two seasons when the doldrums stand over the warm seas between the equator and Asia: one in May, as the doldrums are moving north; one in October, when they are moving south; hence in this ocean alone there are two seasons when tropical cyclones occur.

Formerly much destruction was wrought on vessels at sea by the furious winds of tropical cyclones; but now that the season of occurrence, the usual path, and the behavior of the winds of hurricanes have been learned, and now that vessels are built larger and stronger, losses at sea are much less serious than they were a century ago.

When hurricane winds blow over islands in the torrid oceans they may cause much damage to vessels in the harbors by driving them ashore, and to settlements by destroying the houses and plantations. Cocoanut palms may thus be stripped of their leaves, after which the trees require a number of years of growth before again bearing the fruit of which so many uses are made.

The great sea floods by which Galveston, Texas, was devastated in September, 1900, were caused by the winds of a tropical cyclone which brushed the surface waters from the Gulf of Mexico into the streets of the city. Similar sea floods have repeatedly occurred on the lowlands at the head of the Bay of Bengal, drowning many thousands of the people.

50. Rainfall.—Rain, snow, hail, and sleet are all included under the general term *rainfall.* The explanation already given in Section 30 has shown how closely the amount and season of rainfall are connected with the circulation of the atmosphere.

Snow occurs when the moisture of the air is condensed at temperatures below the freezing point (32°). Snow flakes are six-rayed ice crystals of various patterns. Rain occurs when the moisture of the atmosphere is condensed into drops at temperatures above the freezing point, or when the snow flakes of lofty clouds descend into the warmer lower atmosphere and melt before reaching the ground. Sleet is half-melted snow.

Hail is a mixture of ice and snow, usually in rounded pellets, sometimes half an inch, rarely an inch, in diameter. It occurs chiefly in summer, when the ascending currents of lofty thunderstorms carry raindrops so far upward that they are frozen and coated with snow before they fall. Hailstorms occasionally do much damage to crops and buildings.

Hail should not be confounded with the little pellets of nearly transparent ice, properly called frozen rain, caused by the fall of raindrops from a cloud whose temperature is above 32° through a lower stratum of freezing air. Hail occurs chiefly in hot summer weather; frozen rain in winter.

The amount of rain is determined by measuring the depth of water that is collected in a cylindrical vessel having vertical sides, called a rain gauge. The gauge should be set in an open space, away from trees and

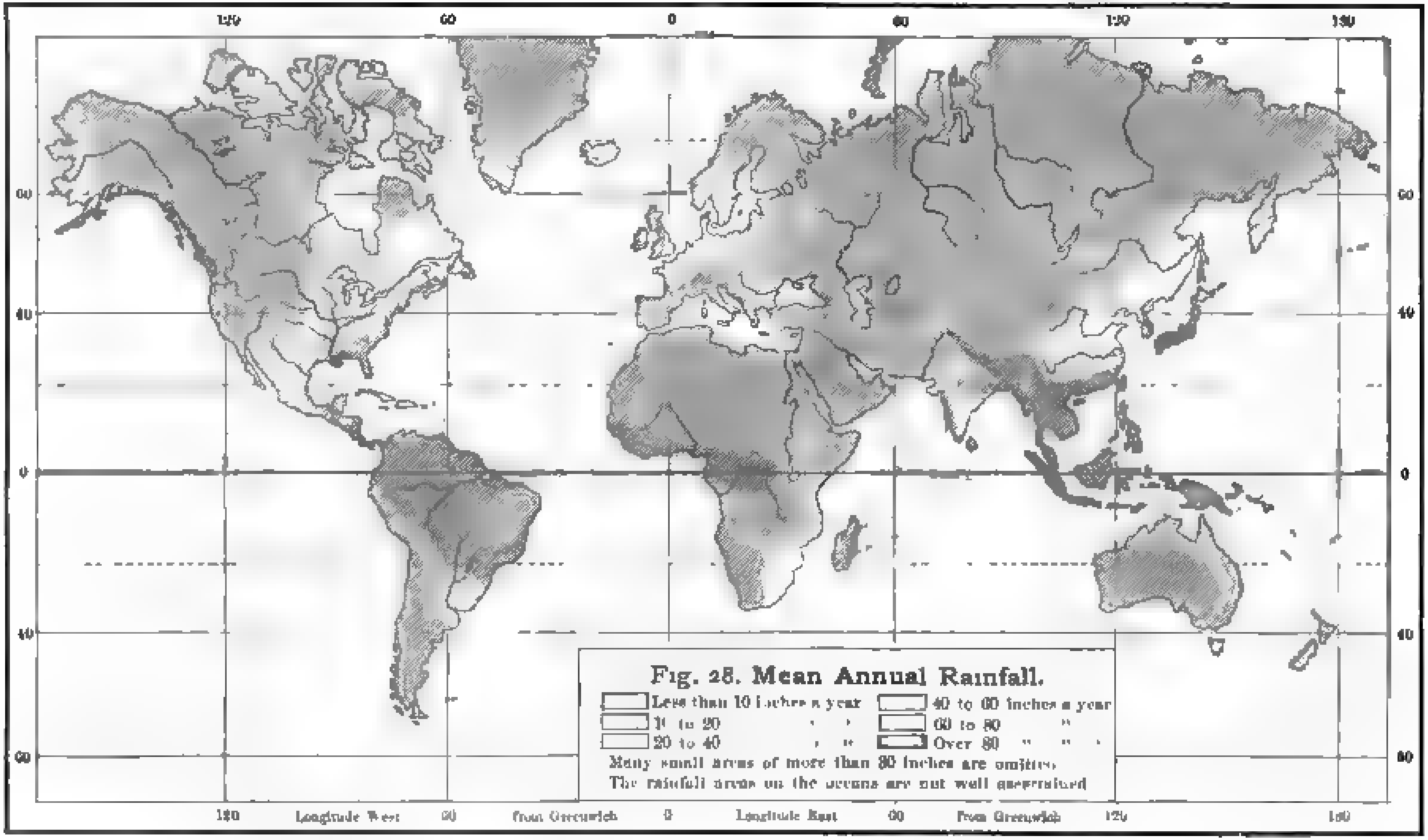

Fig. 28. Mean Annual Rainfall.

buildings. Snow should be melted before it is measured. Eight or ten inches of snow correspond to about an inch of rainfall. An annual total of eighteen, twenty, or more inches is necessary for agriculture, as over the great prairie region of the Mississippi and Ohio valleys from the 95th meridian eastward. If the annual amount is between eighteen and ten inches, agriculture requires irrigation, as on a large part of the Great plains east of the Rocky mountains, and over large areas in the basins of Utah and Nevada; but scattered grass sufficient for cattle ranges may grow in such regions. If the annual total is under twelve or ten inches, there will not be water enough for irrigation, unless it is supplied by rivers that rise in a moister climate, as in parts of Arizona and southeastern California.

The distribution of the annual rainfall over the world, represented in Figure 28, shows that the greater amounts (eighty inches or more) occur in the subequatorial belt and on mountain slopes ascended by the trade winds or the prevailing westerlies. Most of the dry and desert regions of the world (twenty inches of rain or less) are either lowlands of the trade-wind belt, like the Sahara and central Australia, or the slopes and lowlands to the leeward of lofty mountains, as in Peru, or continental interiors crossed by the westerly winds, as in central Asia.

Exercise. Where are the regions of heaviest rainfall? How are these regions related to the belts of the terrestrial winds? to coast lines? to mountain ranges? Where are the regions of light rainfall? How are these regions related to the terrestrial winds?

The heaviest rainfall in the world occurs on the southern slopes of the Himalayas, north of the Bay of

Bengal. Here the rainfall of a single year would measure thirty-five or forty feet in depth, and much more than half of this amount falls during the summer half year when the southerly monsoon is blowing. On the bold southwest coast of India an annual fall of over thirty feet occurs.

The greater parts of western Europe and of eastern North America are fortunate in receiving a plentiful but not excessive rainfall.

In the polar regions the annual snowfall, melted, would seldom exceed fifteen inches of water, and would frequently be less than ten. This is because cold air cannot contain much vapor, and because when cold air is cooled there is but little vapor condensed from it. In the torrid zone the equatorial rains are heavier because warm air can contain a large quantity of vapor, and when warm air is cooled it yields an abundant condensation of moisture.

51. Rainfall of the United States. — The rainfall of the United States may be considered under three headings: the Pacific slope, the western interior region, the eastern region. The Pacific slope has plentiful rainfall in the north (over sixty inches), where the storms of the westerlies are common; but it has light rainfall in the south (under thirty inches), because here the westerlies turn southward to join the trades, and storms are infrequent. The westerly winds are stronger and stormier in winter than in summer; hence the rainfall of Washington and Oregon is heavier in the winter than in the summer

months. The belt of westerly winds reaches farther south in winter than in summer; hence the rainfall of southern California is almost entirely confined to the winter months, while the summers are very dry, thus illustrating the features of the subtropical belt.

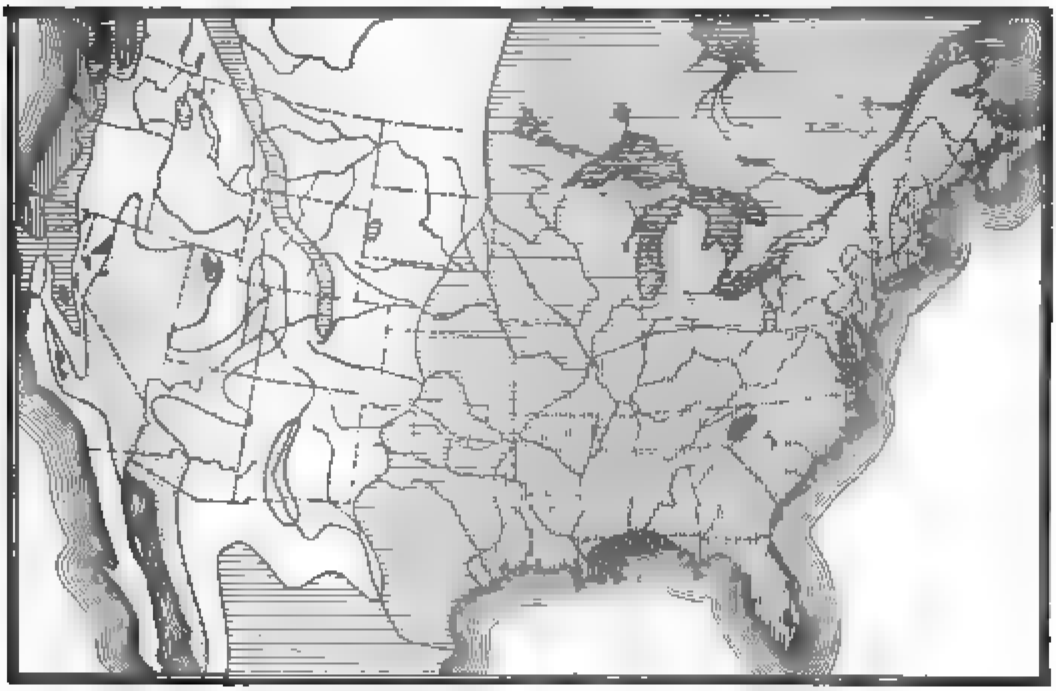

FIG. 29. Annual Rainfall of the United States

Darkest shade, over 80 inches. Lighter vertical lines, from 40 inches to 80 inches. Horizontal lines, from 20 inches to 40 inches. Blank, from 10 inches to 20 inches. Dotted, less than 10 inches.

The western interior region, from the Cascade and Sierra Nevada mountains to the 100th meridian, has moderate or plentiful rainfall on the mountains and high plateaus, because the air is cooled and some of its moisture is condensed as the westerly winds rise over these elevations. The lower lands, as in the basins of Utah and Nevada and over the Great plains that slope eastward from the

Rocky mountains, have light rainfall. The winds here, already dried by losing much of their moisture in crossing the ranges farther west, are seldom cooled enough to form clouds and to yield rain. Hence much of this region is arid. A large part of Nevada, Utah, and Arizona is too dry to yield pasturage; elsewhere a thin growth of grass suffices to support cattle if they have a large area over which to range. Agriculture is seldom successful in this region without the aid of irrigation.

The eastern region is not distinctly separated from the western; the rainfall gradually increases eastward, as moisture is supplied in greater quantities by southerly winds from the Gulf of Mexico and from the Atlantic. Over most of this great region rainfall is well distributed through the year (over forty or fifty inches); somewhat more falls in summer than in winter over the mid-Mississippi basin. The heaviest fall (over sixty or eighty inches) is on the states bordering the Gulf of Mexico (not including Texas), and on the mountains of North Carolina.

52. Weather Changes. — The term *weather* includes all the atmospheric conditions that an observer may feel or see, — hot or cold, clear or cloudy, dry or wet, windy or calm.

In the torrid zone the weather is marked by regular changes from day to night; the changes are small at sea and greater on land, and they are seldom interrupted by storms, except that afternoon thunderstorms are common in the belt of equatorial rains. In the summer season of

temperate latitudes weather changes are usually of moderate amount. In winter the weather of temperate latitudes is largely controlled by the passage of cyclonic and anticyclonic areas, which are then numerous and large, while the control by the change from day to night is relatively weak.

In frigid latitudes the change of weather from day to night is always weak compared with the changes caused by the passage of the great atmospheric whirls.

The relation of weather changes to the spiraling winds of the prevailing westerlies may be simply illustrated by drawing (on an appropriate scale) the winds and clouds of a cyclonic and an anticyclonic area, as in Figure 16, on tracing paper and moving the paper slowly to the right, across a map of the United States. Let the center of the cyclonic area be supposed to move, for example, in four days from Colorado past Lake Michigan and down the St. Lawrence river. Note the changes of wind and weather at Indianapolis, or some other place, as the spiraling wind areas advance eastward. Consider the temperature of the regions whence the winds come in winter and summer, Figures 18 and 19, and infer the changes of weather that they will bring. In the diagram for winter weather the area of the spiraling winds should be larger than in summer; the cloud sheet about the cyclonic center should be larger and the winds stronger.

A series of cyclonic areas sometimes pass by at the rate of two in seven days, thus causing a repetition of a certain kind of weather on the same day of the week for several weeks together.

53. Summer Weather in the United States.—A well-marked series of weather changes over the central and eastern United States in summer may open with fair weather and bright blue sky; the days are warm but not oppressive; the nights are cool and refreshing. Then, if a cyclonic center appears a thousand miles or so to the west, the wind changes to a southerly source, so that it comes from the warm waters of the Gulf of Mexico and the warmer land of the Southern States. The air becomes hazy and the sky pale blue; the days are sultry and oppressive, and the nights lose their refreshing coolness; the ground is dried and parched, and vegetation suffers. The great corn crop of the Mississippi valley may profit by these high temperatures if they do not last too long, but manual labor is exhausting under the blazing sun, and sunstrokes occur in increasing numbers.

Scattered thunderstorms are then reported for a day or two in the afternoon and evening. These are followed by a more extended cloudiness as the cyclonic center approaches, and general rains may fall over several states near the low-pressure center. Thunderstorms of great size are sometimes formed in the moist southerly winds, occasionally giving rise to destructive tornadoes. As these local storms pass by, the cooler northwesterly winds in the rear of the low-pressure center come from the far northern plains. The clouds drift away eastward, the pressure slowly rises, the temperature falls 20° or more, and damp sultry air under heavy clouds is exchanged for fresh air with bright blue sky. Then, as the westerly winds weaken, a southerly breeze springs up and all these changes are repeated.

54. Winter Weather in the United States.—In winter the succession of weather changes is controlled even more distinctly than in summer by the passage of cyclonic and anticyclonic areas. A period of fine, cold, anticyclonic weather usually has a cloudless sky with light winds. The weak sunshine of a short midwinter day cannot overcome the strong cooling by radiation during the long clear night, and the temperature at dawn sinks to a low degree. But as the anticyclone moves eastward the pressure begins to fall. Then long filaments of lofty cirrus cloud float slowly over from the west, announcing the approach of a cyclonic center, the wind turns to a more southerly source, and the temperature slowly rises.

As the cyclonic center draws near, the wind strengthens, the sky is more heavily overcast, and the temperature rises more distinctly, for the source of the winds is now over the tempered waters of the sea on the south and southeast. The rise of temperature may continue steadily through the night, so that midnight and dawn are warmer than the previous noon; for the southerly wind may be more powerful as a cause of warming than the cloudy night is as a cause of cooling. The lowering clouds let fall their rain or snow; if rain, the snow of former storms is rapidly washed away; if snow, the drifts of former storms are deepened and the country is shrouded in white far and wide. It is under the long-lasting snow cover that the "winter wheat" of the northern prairies, sown in November, is protected from the extreme cold of the winter winds, for the snow is an excellent non-conductor.

As the cyclonic center moves on, the northwesterly winds follow it and the pressure rises. The rain or snow ceases;

the clouds break up and drift away to the east and reveal a brilliantly clear sky. The cold northwesterly gale that has come from the far northern plains, west of the cyclonic center, now arrives as a "cold wave." These winds may be from 30° to 50° colder than the southerly winds. A fall of temperature may thus be produced steadily through the day, so that noon is colder than the previous midnight.

If the cold gale is accompanied by falling or drifting snow, it is called a blizzard, a dreaded storm on the plains and prairies. As the temperature falls, furnaces must be made hotter to keep houses warm, and destructive fires then become more frequent than usual. The cold winds may sweep far south, causing great damage to southern crops. Then, as the storm center moves eastward, the winds farther in its rear weaken; the nights become calm and the temperature falls to its lowest degree, and thus another spell of fine and intensely cold weather is ushered in.

55. Summer and Winter Weather in Temperate Latitudes. — Both in winter and summer all the changes here described as connected with areas of high and of low pressure are felt earlier in the west than in the east. The eastward passage of cyclonic or low-pressure areas, illustrated in Figure 30, is controlled by the prevailing eastward atmospheric currents in middle latitudes; and the direction of the currents is determined, as has been stated, by the earth's rotation. In summer time the difference of pressure between cyclonic and anticyclonic centers in North America is relatively small (from 0.5 to 0.8 inch); hence the spiraling winds are then relatively

light. Moreover, the southern and northern regions whence the inflowing spiral winds are then drawn have temperatures not greatly different (about 85° and 65°); hence the changes of temperature are moderate. The eastward movement of the cyclonic areas is relatively

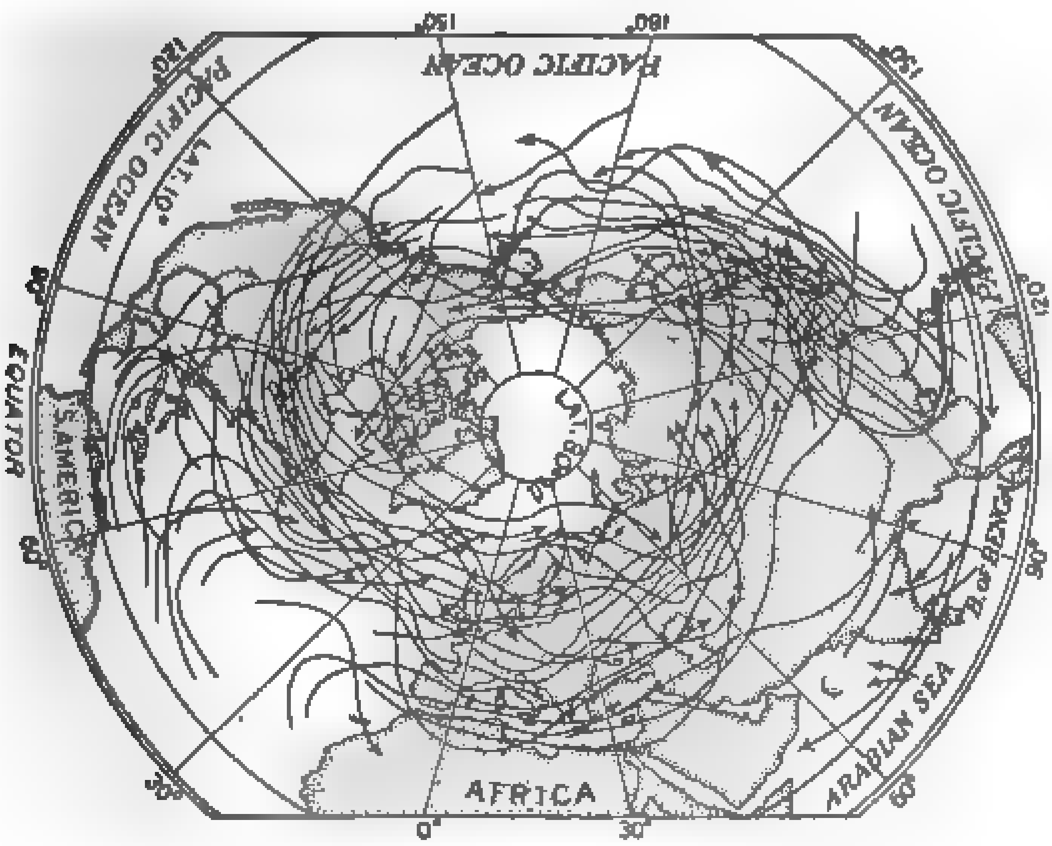

FIG. 30 Storm Tracks of the North Temperate Zone

slow (500 miles a day in the United States); hence the weather changes are gradual.

All this is changed in winter. The differences of pressure are doubled (from 1.0 to 1.5 inches) and the winds often gain the strength of gales; the regions whence the southerly and northerly winds are drawn upon the Central States have very unlike temperatures (80° and 0°),

and the contrast between the warmth in the front and the cold in the rear of the cyclonic areas is very marked. In the winter hemisphere the general winds are quickened, especially in middle latitudes; and therefore the centers of high and of low pressure drift eastward faster (800 miles a day). Besides all this, the cyclonic and anticyclonic centers are more numerous in winter than in summer; hence weather changes in winter are frequent as well as rapid and strong. Winter is therefore a time of stormy changes as well as of low temperatures, thus resembling the conditions of the frigid zone; while summer weather is comparatively even at a high temperature, like that of the torrid zone.

56. Ocean Storms. — The stormy areas of the westerly winds drift from North America out upon the northern Atlantic ocean, as shown in Figure 30. Gales attend their passage, especially in the winter season, when a voyage across this ocean is much rougher than in summer. The gales caused by these storms are usually on the southern side of the low-pressure center, and hence from a western quarter. The general course of the storm centers is northeastward, so that a cyclonic center that passes over New England or down the St. Lawrence valley is more likely to affect the weather of Norway than that of Spain. Storms from the North Pacific ocean come upon the western coast of North America; they may before breaking up pass far inland or even cross the whole breadth of the continent. The storms in the prevailing westerly winds of the southern hemisphere encounter but little land in their

course. They are more severe in the southern winter (June to August) than in the summer (December to February). South America reaches farther south than the other continents; hence vessels rounding Cape Horn must enter much farther into this stormy belt than in rounding the Cape of Good Hope, and the passage around Cape Horn is dreaded for this reason.

57. Cyclonic Winds.—The inflowing spiral winds of cyclonic storms are often given special names in different parts of the world, according to the kind of weather they may bring. The cold wave of our winters, sweeping over the central and eastern United States from the far northern plains in the rear of cyclonic centers, has already been described. In western Europe the cold wind of winter is the northeaster, because the plains of northeastern Europe supply colder air than the ocean about Iceland. It occurs when a cyclonic center follows a more southerly track than usual. The blizzard of our plains corresponds to the buran of Siberia. No special name has been given in the United States to the sultry southerly wind that frequently brings unseasonably warm weather in front of a cyclonic center. It might be called a sirocco, after the Italian name of a similar wind. In the southern hemisphere cold winds come from the south, and hot winds from the north. In southern Australia the wind that corresponds to the sirocco is called a brickfielder, because it bakes the fields hard and dry.

58. Weather Predictions.—Weather maps from which the general character of the weather for one or two days

may be predicted are now prepared daily in many countries. Observations of the weather made at the same hour at many different places are telegraphed to the central station, — the Weather Bureau at Washington for the United States. They are then promptly charted so that the areas of high and low pressure, the temperature, the direction and strength of the winds, the distribution of clear and cloudy sky and of rain or snow are all shown. It is known, as described on preceding pages, that cyclonic and anticyclonic areas with their attending weather conditions usually move eastward; it is therefore possible to foretell with considerable accuracy the weather that may be expected for a day or two in various parts of the country from the conditions shown on the weather map.

Predictions thus prepared are distributed by telegraph, and published in special bulletins and in newspapers for the benefit of the public.

No one has yet succeeded in making successful predictions of the weather regularly for definite districts several weeks or months in advance. It is true that such "long-range predictions," as they are called, are frequently published. As the weather differs in different parts of the country, predictions of hot weather over the central United States in July and of cold weather in January, or rain in March and drought in September, may be correct for one place or another, but they must be incorrect for other places. Such predictions cannot be depended upon.

59. Climate. — The general succession of weather changes through the year, averaged for many years,

constitutes the climate of a region. The five climatic zones into which the earth is commonly divided need further subdivision in order to correspond to the many well-marked types of climate on lands and seas, on coasts and inland regions, on lowlands and highlands.

The trade-wind belt at sea has the simplest climate in the world, with small daily and yearly changes of temperature. The steady wind and fair weather of almost any day give a fair sample of the year. Low lands under the regular trade winds suffer greater daily and yearly changes of temperature, with light rainfall.

Compare the mean annual range of temperature in the West Indies and in inner Africa, latitude 20° N., Figure 20; in Africa, Indian ocean, and Australia, latitude 20° S.

The subequatorial belt has a distinct seasonal change as the clouds of the heat equator move away and give place to the dry trade winds. The Sudan, between the desert of Sahara and the forest belt of equatorial Africa, has plentiful rainfall and active plant growth when the equatorial cloud belt moves north, bringing the wet season (May to August), but it becomes parched, barren, and dusty under the trade winds of the dry season (December to March).

Examine Figure 21 and state in what months you would expect rain on or near the geographical equator. At the head of the Gulf of Guinea, west equatorial Africa, rain is most abundant in March and October to November. In Ceylon the rainfall is greater in May and October than in the other months; at the city of Quito, Ecuador, in April and November. How do you explain these double rainy seasons?

The south temperate zone is mostly an oceanic belt. The changes of air temperature with the seasons are small, as shown in Figure 20, because the water surface warms and cools so little in summer and winter. Its winds are more stormy in winter, less stormy in summer; never very hot or extremely cold, but for the most part chill, damp, and blustering. Islands near 50° S. are hardly habitable, not that the winters are too severe, although cloudy and wet, but that the summers are too chilling.

The north temperate zone contains large areas of both land and water, and the temperatures of its various parts are therefore very unlike, as shown in Figures 18, 19, and 20. The parallel of 50° N. crosses regions whose climates are so different that they would hardly have been placed under a single zone had they been studied before being named; but the name was given from the truly temperate climate of southern Europe, before other parts of the world were well known.

Beginning in the moderate climate of the North Atlantic, Figure 20, the parallel of 50° N. enters the favorable climate of middle Europe, where the last thousand years have witnessed the greatest human progress in the arts and sciences that the world has ever known. It crosses the broad deserts of central Asia, where the scattered population is held down in barbarism chiefly by severe and unfavorable climatic conditions.

The broad North Pacific has in this latitude a climate as moderate as that of the North Atlantic. Passing the tempered and moist climate of the coast belt of British Columbia, and crossing the snowy mountain ranges beyond,

the severe interior climate of middle Canada is reached, with extremes of temperature, summer and winter, only less than those of inner Asia. As far as habitability is concerned, the middle north temperate zone contains climatic differences almost as great as those found in passing from the equator to the pole.

Compare this account of the climate of latitude 50° N. with the conditions in latitude 50° S.

Supplement to Chapter II

60. Deflection of Winds by the Earth's Rotation.— Place a marble in the center of a circular board. Set the marble in motion by striking it a light blow. It will move in a straight line along a radius from center to circumference. Now let the board be given a slow movement of rotation around a pivot at its center. The marble will now again move directly outward, but the line that it traces on the turning board will be curved so as to fall behind the radius on which it started. If the board turns to the left, the marble will be deflected to the right of its original path; if the board turns rapidly, the deflection will be strong.

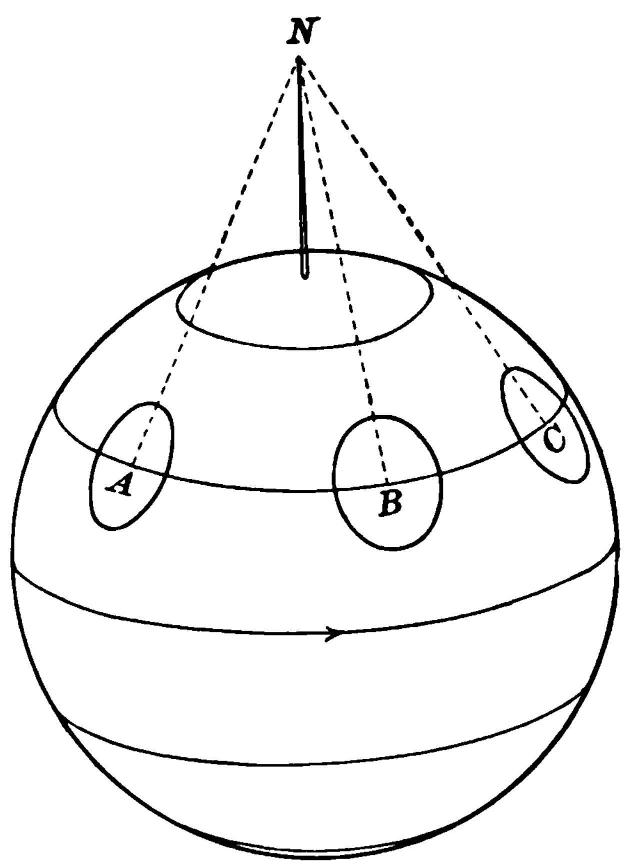

Fig. 31. Rotation of a Disk on a Rotating Globe

In Figure 31 the circle, *A*, resting on the earth in a northern latitude may be taken to represent a circular board or surface of great size. A north line drawn from the center of the circle meets the prolonged axis of the earth at *N*. When the rotation of the earth has carried the circle to *B* the same north line has a new direction, *BN*,

showing that the circle has turned somewhat to the left with respect to its own center. Hence any such circle may be taken to represent a turning surface. A body beginning to move in any direction from the point A will tend to turn to the right, because of the rotation of the circle to the left. This tendency will be strongest at the pole, because a circle there rotates with the greatest rapidity, turning completely round in twenty-four hours. The tendency is zero at the equator, because there a circle has no movement of rotation with respect to its own center. In the southern hemisphere, where the circle must turn to the right, the deflective force acts to the left.

The wind is so free to move over the earth's surface that it is greatly affected by the deflective force arising from the earth's rotation. Hence the members of the atmospheric circulation do not flow north and south, but are always deflected to the right of these directions in the northern hemisphere, and to the left in the southern.

The lofty overflow currents are deflected so as to run from the southwest or even from the west-southwest in the northern hemisphere, from the northwest or west-northwest in the southern. The winds approaching the equator do not blow directly from the north and the south in the two hemispheres, but are deflected so as to blow from the northeast and southeast, forming the trade winds. The whirling winds of cyclonic storms, described on pages 45 and 67, attempt to blow toward their centers of low pressure, but on account of the earth's rotation the winds are deflected to the right in the northern hemisphere, and to the left in the southern; thus the storms are given their whirling movement.

It should be noted that winds will be deflected to the right or left, in whatever direction they begin to blow, east and west winds being affected just as much as north and south winds. Ocean currents are similarly affected but to a less degree, because they move more slowly than the winds. Rivers tend to turn to the right in the northern hemisphere and to the left in the southern; but the tendency is practically overcome by the resistance of the banks. Similarly a railroad train tends to be deflected, but is held to its track by the flanges on the wheels.

61. Practical Method of studying Observations of the Sun. — In studying the control of the seasons by the sun it is desirable to determine the length of the day and the midday altitude of the sun by observations about once a fortnight, or at least once a month, through the school year, with additional observations near the times of shortest and longest days or of lowest and highest midday sun.

If sunrise comes at too early an hour for convenient observation, note that midday occurs at the middle of the interval between sunrise and sunset. Midday is determined by the method explained on page 8. The time of sunset may be directly observed. The time of sunrise may then be determined by counting back as many hours and minutes before midday as sunset occurs after midday.

The midday altitude of the sun may be determined as follows: Use such a box as is shown in Figure 3, and drive a pin square into one side of the box, close to its upper corner. With the pin as a center, draw an arc of a circle on the box side. Draw a horizontal and a vertical line from the pin to the arc. The arc included between the two lines will be a right angle, or 90°. Divide it into halves, divide the halves into thirds, and the thirds again into thirds. The small divisions thus found will be 5° of arc. Number the divisions from 0 at the horizontal line to 90° at the vertical.

As the sun approaches the meridian, turn the side of the box so that it is directed toward the sun. The shadow of the pin is then seen as a slanting line, and the altitude of the sun is indicated by the angle that the shadow line makes with the horizontal line. Continue to turn the box after the sun, until the altitude indicated by the shadow line begins to decrease. The greatest angle thus found is the midday altitude of the sun.

In Figure 32 let the horizontal scale represent the days of the year, and the vertical scale the angular altitude of the sun at midday. Mark the sun's midday altitude by dots opposite the appropriate dates. At the close of the school year draw a curve through the dots. Draw lines parallel to the base line and touching the upper and lower points of the curves. Draw a third line midway between the last two.

In Figure 33 the vertical scale represents the days of the year; the horizontal scale measures hours before and after midday. Mark dots to the right and left of the midday line and opposite to the appropriate dates, to represent the time before and after midday at which sunrise and sunset occur. Connect these dots by curved lines. Draw two lines that shall stand six hours on either side of the midday line.

Now determine from Figure 32 the dates when the sun has the greatest midday altitude (or when it stands farthest north in the sky) when it has the least midday altitude (farthest south in the sky),

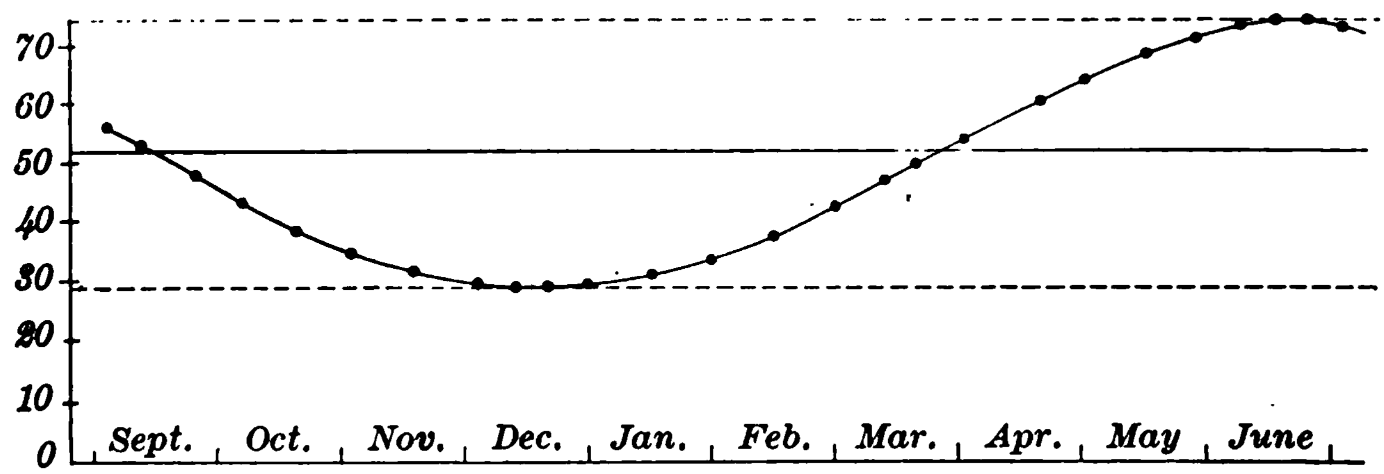

FIG. 32. Diagram of the Sun's Midday Altitude

and the two dates when its altitude is that of the mid-horizontal line. Determine from Figure 33 the date when the day is longest, when it is shortest, and the two dates when it is twelve hours long. Compare the dates thus found. If the observations are well made and the diagrams accurately constructed, the four dates should agree on the two diagrams.

The dates when the days are twelve hours long, and therefore equal to the nights, are March 21 and September 22; these dates are called the vernal (spring) and autumnal (fall) equinox (equal-night). The date when the sun is farthest north, and when the day in the northern hemisphere is consequently longest, is June 21. This is called the summer solstice (sun-stand), because the sun, having then finished its northward movement, stops or "stands" before beginning its southward movement. The day when the sun is

farthest south, and when the day is consequently shortest in the northern hemisphere, is called the winter solstice; this date is December 21.

Between what dates is the sun moving northward in the sky? Between what dates is it moving southward? Between what dates are the days lengthening?

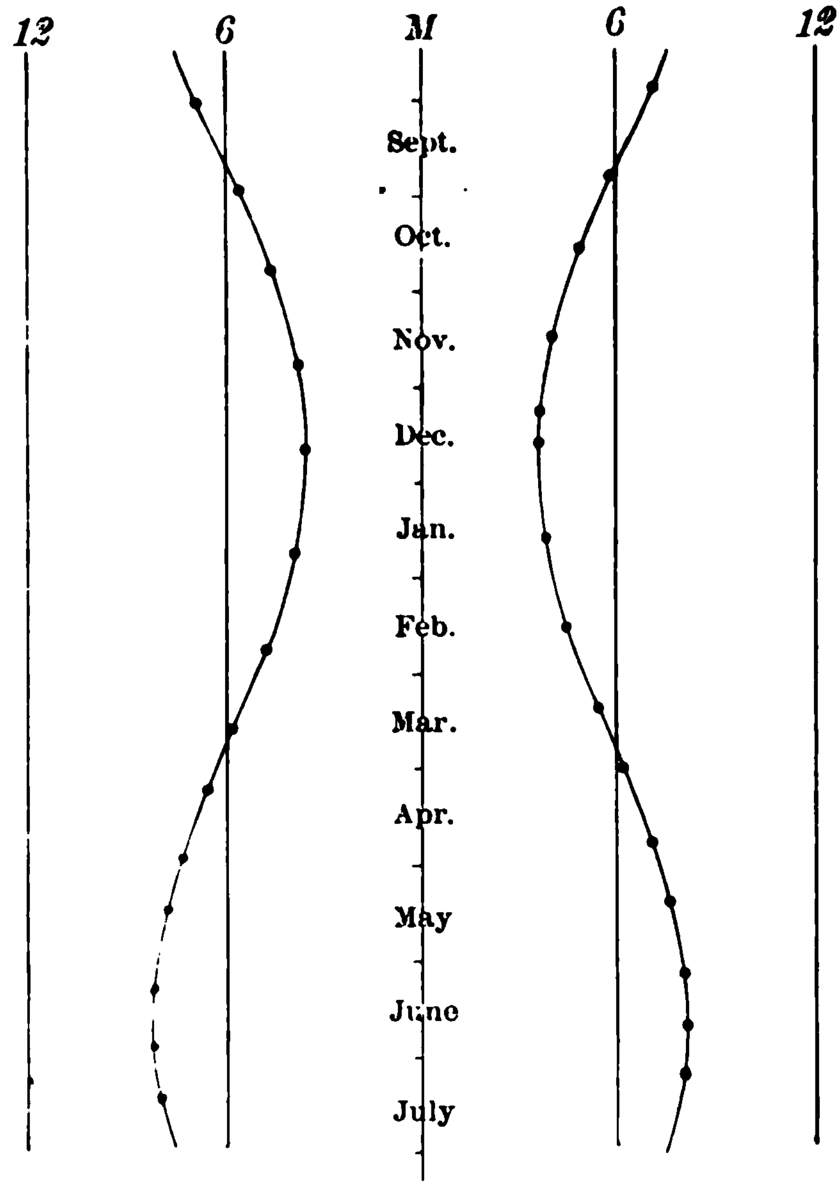

FIG. 33. Diagram of Sunrise and Sunset Hours

At the time of the equinoxes the sun must be on the equator of the sky; for, as is shown in Figure 17, it is only then that equal days and nights occur in all parts of the world. Hence the middle horizontal line in Figure 32 must represent the angular altitude of the sky equator where it crosses the meridian. The angular distance of the sun north or south of the sky equator for any day of the year may be measured by the scale at the side of the figure. The greatest angular distance of the sun from the sky equator gives means of determining the limits of the zones. (See page 48.)

How far north of the sky equator does the sun stand at the time of the summer solstice? How far south at the time of the winter solstice? How many days is it north of the sky equator? How many days south?

62. Determination of Latitude. — The sky equator passes overhead (in the zenith) to an observer at the earth's equator; hence the sky equator will depart one degree from the zenith for every degree that

the observer moves toward the pole. Therefore the latitude of a place must equal the angular distance of the sky equator from the zenith. Latitude may thus be determined on any day by measuring the sun's midday altitude and allowing for its distance from the sky equator, as determined by Figure 32. The altitude of the sky equator subtracted from 90° is the latitude. Results that are correct within a few degrees may be obtained even by the rough observations here described.

If records of the kind indicated above are taken on different dates in successive years, the increasing number of dots will give better and better definition of the curves in Figures 32 and 33; but minute accuracy of performance is not so important as intelligent exercise in the application of principles.

Examples. If the midday altitude of the sun is 50° on the 22d of September, what is the latitude of the place of observation? What would the latitude be if the observation had been made on December 21? on March 21? on June 21?

63. Exercises on Weather Maps. — Many instructive exercises may be based on the daily weather maps. Copies of these maps for school use may be obtained, under certain conditions, by addressing the Chief of the Weather Bureau, Washington, D.C. The exercises here described may be performed on the original maps, or on outline maps of the United States upon which certain weather elements are copied. It is usually best to select maps on which differences of pressure are well defined, in order to exhibit strongly marked types of weather.

64. Distribution of Pressure. — Plat upon a blank map of the United States the barometer readings taken from a weather map, and thus guided draw in lines of equal pressure, or isobars, for every tenth of an inch according to the method already explained for isotherms. The difference of pressure between the highest and lowest readings is often six or eight tenths of an inch or more. Shade the areas of high and low pressure, leaving the area of intermediate pressure (for example, from 29.9 to 30.1 inches) blank. Describe the

distribution of pressure thus shown. Draw a similar map for the next day. Describe the change in the distribution of pressure thus found. Temperature may be similarly treated.

65. Movement of Winds in Areas of High and Low Pressure. — Select several well-defined examples of high- and low-pressure areas whose centers lie in the mid-Ohio valley, so that observations are provided on all sides of them. Plat the wind arrows (the arrow flies with the wind on weather maps), and let their length indicate wind velocity (an eighth of an inch for five or ten miles). Draw additional lines to represent inferred wind movement between the points of observation. How is the direction of the wind at any place related to the distribution of pressure about that place? In answering this question it will be well to draw, through the point considered, a line at right angles to the neighboring isobars. This line shows the direction of increase or decrease of pressure. Describe the general movement of the winds (direction and velocity) with respect to a center of high pressure; of low pressure.

66. Composite Portrait of High- and Low-Pressure Areas. — Rule a straight line through the center of a sheet of tracing paper and mark the ends of the line *N* and *S*. Lay the center of the sheet over the center of an area of low pressure and turn the *N–S* line so that it shall lie most nearly parallel to the adjacent meridians. Trace off the signs indicating the state of the sky (clear, fair, rain, or snow) at various stations. Do the same for several other maps that have a low-pressure center. Do the same on another tracing paper for several areas of high pressure. Compare the results as to the distribution and frequency of clear, fair, and wet weather, with respect to centers of high and of low pressure. Winds may be similarly treated.

67. Progression of High- and Low-Pressure Areas. — Select a series of four or five maps on which a well-defined area of high or of low pressure is represented as occupying successive positions eastward across the country from the Rocky mountains to the Atlantic. Chart on an outline map the path of the center of the

area studied and determine its velocity in miles an hour and a day. Note the weather changes (pressure, temperature, wind, sky) that occur at a single station as the cyclonic or anticyclonic area passes over it. What is the general character of these changes for a cyclonic area? for an anticyclonic area?

Compare the succession of weather changes at any place, as determined from weather maps, with the weather changes observed at school during several days. How are the local weather changes related to passing areas of high or of low pressure (anticyclonic and cyclonic areas)?

QUESTIONS

SEC. 19. What processes depend on the atmosphere? What is known of its height?

20. What is the composition of air? How is oxygen used? carbonic dioxide?

21. What is the pressure of the atmosphere on a square foot of surface? Describe the mercurial barometer; the aneroid barometer. How can barometers be used to measure mountain heights?

22. How does the density of the air vary? Why? What is the weight of a cubic foot of air at sea level? How is sound carried?

23. How are the colors of the sky produced? What is the twilight arch? When may it be seen?

24. How is the temperature of the air controlled? Why is the upper air cold? Consider the diurnal range of temperature in the upper and lower air. How do the processes of absorption, conduction, and radiation affect the temperature of the air? How does the form of the earth affect the distribution of temperature? How is the weight of air affected by heat?

25. What is a mirage? How is it produced on level deserts? on a water surface?

26. Explain the construction of a thermometer. How do the Fahrenheit and Centigrade thermometer scales differ? What is a

thermograph? a maximum thermometer? a minimum thermometer? How should a thermometer be exposed?

27. How are temperature charts constructed? What is an isothermal line? How are mean temperatures determined? What is the heat equator? Describe its position. Compare the mean annual isotherms of the northern and southern hemispheres.

28. Describe the movements of the air between a hot and a cold room. What is a convectional circulation? Describe the general circulation of the atmosphere between equator and poles. What changes of temperature are caused in ascending and descending currents? What is the planetary circulation?

29. How are winds named? How is their strength described? What is an anemometer?

30. Describe the steps in the circulation of water through the atmosphere. How is rain caused?

31. What are the chief members of the planetary winds? Describe the trade winds. Where do they occur? What is their direction? What is the relation of rainfall and deserts to the trade winds? of wet and dry mountain slopes to the trade winds? Give examples. Describe the prevailing westerlies. Where do they occur? What is their direction? How is rainfall related to these winds? What are the doldrums? the horse latitudes? Describe and explain the weather of the doldrums; of the horse latitudes.

32. Describe the whirls of the westerly winds. Explain their weather. How fast do they travel? Compare the whirls of the two hemispheres. Compare the atmospheric pressure at the center of the inward and outward whirls. What names are given to these whirls?

33. Describe the movement of the earth around the sun. Compare the attitudes of the northern and southern hemispheres with respect to the sun in the two half years. What are the resulting variations of temperature? What are the months of each of the four seasons in the northern hemisphere? in the southern? What are the limits of the torrid zone? the frigid zones? the temperate zones?

34. What are the apparent movements of the sun in December? in June? How are the temperatures of winter and summer related to these movements? Explain the rising temperature of spring; the falling temperature of autumn.

35, 36. How may the change of seasons be described if the earth as a whole is considered? Mention the most striking facts shown on the isothermal charts for January and for July.

37. Describe the most striking facts shown on the chart of mean annual temperature range. Compare the annual range of temperature over the northern continents and the southern oceans; on western and eastern coasts in temperate latitudes. Why are the annual changes large in the northern hemisphere? Why small in the southern?

38. How do the terrestrial winds differ from the planetary? Explain the differences. Describe and explain the subtropical belts. Name some countries lying in a subtropical belt and describe them as to winds and rainfall. Describe and explain the subequatorial belt. Describe its migration, Figures 22, 23, on the Atlantic ocean; on the eastern Pacific; on the Indian ocean. Give some examples of subequatorial rainfall in South America; in Africa.

39. What are monsoons? How are they caused? Where do they occur, Figures 22, 23? Describe the monsoons of the Indian ocean.

40, 41, 42. How do the continents affect the terrestrial winds? Give examples from Asia. What are land and sea breezes? How do fair-weather winds on lands vary from night to day? Explain this variation. Why does it not occur at sea?

43. What is humidity? How does it vary with temperature? What is saturation? Compare the feeling of damp and dry air.

44. What is the dew-point? How may it be determined? What are dew and frost? Under what conditions are they produced?

45. Describe the chief kinds of clouds: cumulus, cirrus, cirro-stratus, alto-nimbus, and nimbus. Describe a halo; a corona.

46, 47, 48. Describe a thunderstorm. Where and when do such storms occur? What can you say about lightning and thunder? What is a cloud-burst? a rainbow? a tornado? a waterspout?

49. Where and how are tropical cyclones formed? How do their winds blow? How do these storms travel? In what regions do they occur? In what months? Why are there two seasons of cyclones in the northern Indian ocean? Why are tropical cyclones not formed in the South Atlantic?

50. What is meant by rainfall? Describe and explain snow; rain; hail; frozen rain. How is rainfall measured? State the relation of rainfall to agriculture. Give several examples of the relation between the terrestrial winds, Figures 22, 23, and rainfall, Figure 28. Where is the heaviest rainfall of the world? What is its amount? its cause? Why is the rainfall of low latitudes large, and of high latitudes small?

51. Describe the rainfall of the Pacific slope of the United States; of the interior region; of the eastern region.

52. What is meant by weather? Describe the prevailing weather of the torrid zone; of the temperate zones in summer; in winter; of frigid latitudes. Explain the effects of cyclonic and anticyclonic areas.

53. Describe a period of summer weather in the eastern United States as a cyclonic area is approaching; after it has passed. When are sunstrokes and thunderstorms most common?

54. Describe our winter weather in front of a cyclonic area; in the rear. When may a warming night occur? a cooling day? What is a cold wave? a blizzard?

55. Describe the tracks of high- and low-pressure areas in the north temperate zone. What changes of pressure do they cause in summer? in winter? How fast do they travel in summer? in winter? Compare the changes of temperature that they produce in the central part of United States in summer and in winter.

56, 57, 58. Describe the storms of the North Atlantic. What is a buran? a sirocco? a brickfielder? How is the weather predicted?

59. What is climate? Describe the climate of the trade-wind belt at sea; of the subequatorial belt; of the south temperate zone; of the north temperate zone on the oceans; on the lands. Describe the climates of latitude 50° N.; of latitude 50° S.

CHAPTER III

THE OCEAN

68. Form of the Ocean. — The ocean is a sheet of salt water, clear and blue, covering about three quarters of the earth's surface to an average depth of about two miles. It lies in broad depressions or basins between the continents, its shallow edges lapping over the margin of the continental masses.

The outline and distribution of the ocean are best studied on a globe. A vast water area, comprising the Pacific and Antarctic oceans, covers nearly half the earth. The water surface is broken only by Australia, the Antarctic lands, and many small islands. A short Indian arm extends from this great oceanic area into the space between Africa and Australia, and a long, relatively narrow Atlantic arm runs between the Old and New Worlds, ending in the gulf-like Arctic ocean around the north pole.

The surface of a hemisphere whose pole is near New Zealand is nearly all water, as in Figure 34; while the opposite hemisphere contains all the large land areas, except Australia, the Antarctic lands, and the extremity of South America. It is not a little curious to note that near the pole of the land hemisphere stands the greatest city of the world, the capital of the empire whose colonies are more widely spread than those of any other nation.

What lands lie entirely in the land hemisphere? What oceans lie largely in the land hemisphere? Trace the course of the great circle which divides the land and water hemispheres.

69. The Ocean as a Highway.—The lands are widely separated by the oceans, and navigation of the "high seas" requires great skill and is fraught with many dangers. But the oceans are a ready-made highway, where movement

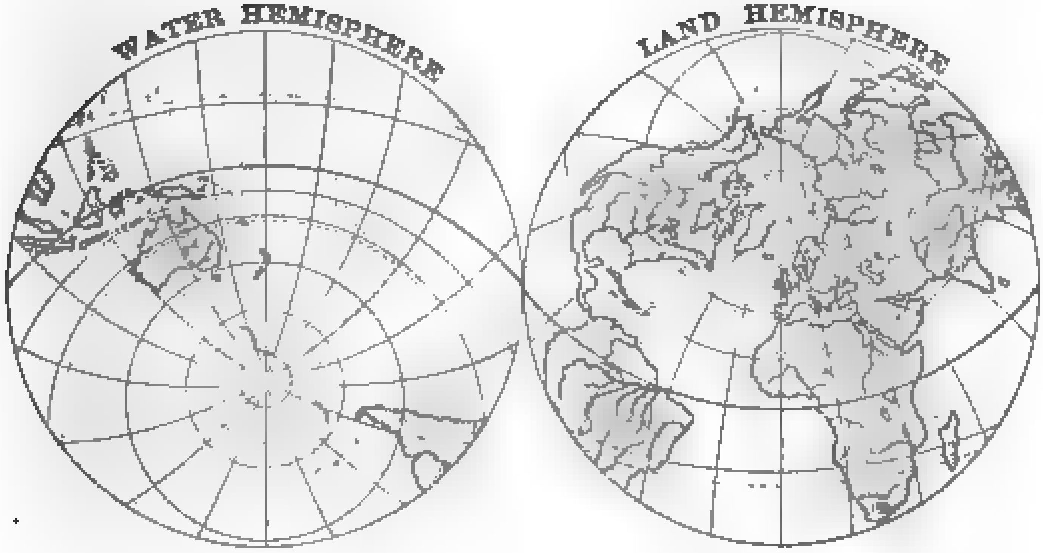

Fig. 34. Water and Land Hemispheres

is easy and open to all comers; the winds furnish free motive power to sailing vessels, and coal is an economical fuel for steamers. Hence ocean-going vessels are used to carry large quantities of merchandise from one part of the world to another.

Before railroads were invented the two sides of the North Atlantic were in more active communication by sea than the two sides of any continent overland. Since railroads have been extensively built inland transportation has greatly increased; but a great part of international commerce is still carried on across the oceans in steamships and sailing vessels.

70. Exploration of the Ocean. — The earlier exploration of the ocean discovered its shore lines on the continents and islands. Exploration in the latter part of the nineteenth century penetrated its depths and reached its bottom.

Soundings are now made with much accuracy, even to depths of four miles or more. Fine steel wire is used for

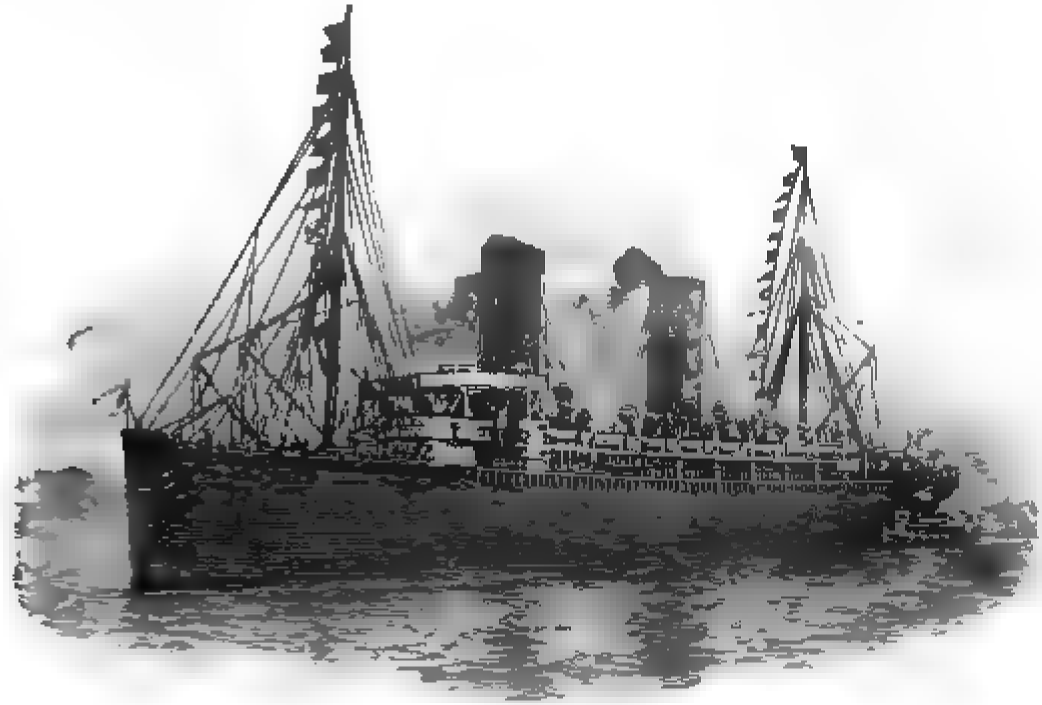

FIG. 35. An Ocean Steamship

a line; the sinker is a heavy iron ball that is automatically detached on touching the bottom; then the wire is rapidly reeled in by steam power. A sounding of 3000 fathoms (one fathom equals six feet), or over three miles, can be completed in about an hour.

The temperature of the deep water is taken by self-registering thermometers. They must be protected by an outer glass tube against the tremendous pressure of the

deep water. Samples of water are obtained from various depths by the use of brass tubes, called water bottles, sent down open but automatically closed when reeling in begins. Specimens of the ocean bottom are gathered by dredges, or strong nets with an iron rim. Wire rope is needed to haul up the ton or more of material that they take in while dragging on the sea floor at depths of one, two, or even three miles. Nets are sometimes attached to the wire rope at different depths, for the purpose of catching animals that happen to enter them. The best nets are closed while sinking and rising, being open only while trolling at the greatest depth that they reach.

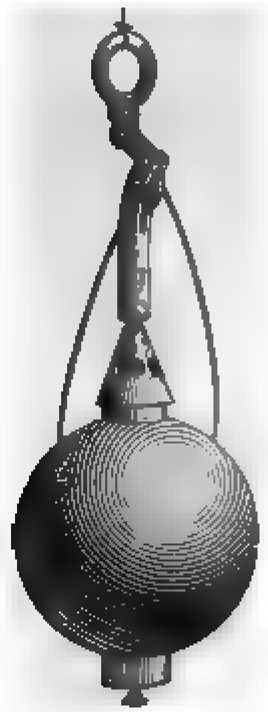

FIG. 36
Sounding Instrument and Water Bottle

71. Ocean Depths.—Soundings have shown that the ocean basins are comparatively steep sided and flat floored. The greatest depth yet found is 31,614 feet, in the western Pacific near the island of Guam (lat. 12° 45′ N., long. 145° 45′ E.). Another place of great depth, 30,930 feet, is in the Pacific, near the Fiji islands.

FIG. 37. Dredge

The deepest sounding yet made in the Atlantic is 27,366 feet, or over five miles, in a local depression 100 miles north

of Porto Rico, West Indies. The Atlantic is generally less deep along its middle (9000 to 12,000 feet) than on either side (15,000 to 18,000 feet), the shallower middle part being sometimes called a *ridge* or *swell*. (See Figure 144.)

72. Composition and Density. — The ocean contains a great variety of substances in solution, for it has received everything that streams have dissolved and carried from the lands for ages past. Common salt makes three quarters of the dissolved substances. An important but much less plentiful dissolved substance is limestone, of which many sea animals make their shells or skeletons.

A small quantity of atmospheric gases is found dissolved in sea water, even in its deepest parts. The gases are taken in at the surface, especially when air is caught in dashing waves. It is upon the oxygen thus supplied that fish and most other marine animals depend for breathing; but whales and other mammals living in the ocean come to the surface for air.

The mineral substances dissolved in ocean water make about three per cent of its weight; their presence makes it a little heavier than pure water (in proportion of 1.026 to 1.000). Although water is easily moved, it can be very little compressed. Hence, in spite of the great pressure of the upper layers of the ocean on those beneath, the ocean is unlike the atmosphere in being of nearly uniform density from top to bottom. Anything that is heavy enough to sink at the top will sink all the way to the bottom.

73. Color and Phosphorescence. — In the open ocean, far from land, the water is extraordinarily clear. It is of a

beautiful deep blue, so strong that one would expect the color to show in a bucket; but if some water is dipped up from the sea surface, it appears perfectly transparent and colorless. In cloudy weather the ocean is of a duller, more leaden hue. Near the lands the blue is lighter and turns toward a greenish shade. Opposite large rivers the water may be yellowish from suspended sediment; the Yellow sea is so named on this account. What large rivers enter it?

There are many small jellylike animals that float in the ocean. Some of these have the power of emitting, when disturbed, a pale light, visible in the dark. They are found chiefly in the warmer parts of the ocean. Breaking waves and the foam in the wake of a vessel may thus become beautifully luminous or phosphorescent at night.

74. Ocean Temperatures. — The surface layers of the ocean vary in temperature with latitude, reaching about 80° around the equator, and being reduced to 30° or 28° in the polar regions (Figure 44). The great body of the deep ocean is cold in all latitudes; its temperature is about 30° in high latitudes and 35° or 40° in the torrid zone.

When exploring vessels dredge in a torrid ocean the sediments brought up from the bottom have a temperature near freezing, strangely in contrast with that of the objects on shipboard under a hot sun.

The sun's rays have small effect on ocean water at depths below 100 or 150 fathoms. At greater depths the ocean must be nearly dark, with hardly perceptible difference between day and night, or between winter and

summer. The temperature at any point in the great body of the deep ocean is therefore nearly constant.

Changes of temperature in the ocean surface through the day or the year are very small, seldom more than 3° and 15°, respectively. As the temperature of the lower air is largely controlled by that of the surface on which it rests, the climate of islands in mid ocean and of continental borders where the prevailing winds blow ashore is free from great changes of temperature between winter and summer.

Salt water becomes heavier and heavier as it is cooled down to its freezing point, 28°. Hence the cold surface water of high latitudes sinks to great depths and creeps very slowly toward the equator; thus the low temperature of the great body of the ocean is accounted for.

Fresh water is unlike salt water in being densest at 39°. On being warmed or cooled from this temperature it expands and becomes lighter. Hence in winter, when all the water of a lake has been cooled to 39°, further cooling affects only the surface water, which may then soon freeze.

75. Ice in the Ocean. — Ice expands a little as it freezes; it therefore floats, about one seventh of its volume being out of water. The ice formed in the polar oceans is known as floe ice; it may reach a thickness of from three to seven feet in a single winter.

Great fields of floe ice drift with the winds and currents. They may thus be torn apart or crushed together. When two floes collide pack ice of very irregular surface is formed; it may reach a thickness of over 100 feet.

In Greely's expedition to the Arctic regions in 1883 his boats were frequently in danger of being crushed when ice fields drifted together, closing the water passage he had been following.

Smooth floe ice is easily crossed on sleds. The Eskimos make winter journeys upon it. Where packed it may be

FIG. 38. A Vessel beset by Pack Ice

impassable. It was on account of the roughness of ridged pack ice that Nansen had to turn back from his "dash for the pole," in latitude 86° 13′ N., longitude 96° E., on April 8, 1895. When two large fields of pack ice drift together a vessel between them would be crushed, unless of great strength and shaped so as to escape by rising. Nansen's vessel, the "Fram," was especially constructed to withstand great pressure and so survived the dangers to which it was exposed.

Icebergs in the North Atlantic are fragments from the ends of great fields of ice (glaciers) that descend into the sea from Arctic lands, chiefly Greenland; they are of fresh water. The tabular icebergs of the Antarctic ocean are fragments of a heavy sheet of ice around the south pole. Some of these ice blocks measure a mile or more

FIG. 39. An Iceberg

on a side, and 1200 to 1500 feet in thickness. Icebergs, being of fresh water, float with about one sixth or one seventh of their volume above the sea surface.

Collision with an iceberg is one of the dreaded dangers of navigation in high latitudes. In the southern oceans drifting icebergs reach latitude 50°, or even 40°. In the North Atlantic they reach latitude 45°, southeast of Newfoundland, but they are absent from the northwestern coast of Europe, even in latitude 70°, on account of the

warm water there prevailing. They are wanting in the North Pacific, except in the seas of northeastern Asia.

76. The Ocean Bottom. — The greater part of the deep ocean bottom is a comparatively even plain of soft ooze. The plain rises and falls gently in broad swells, but is not

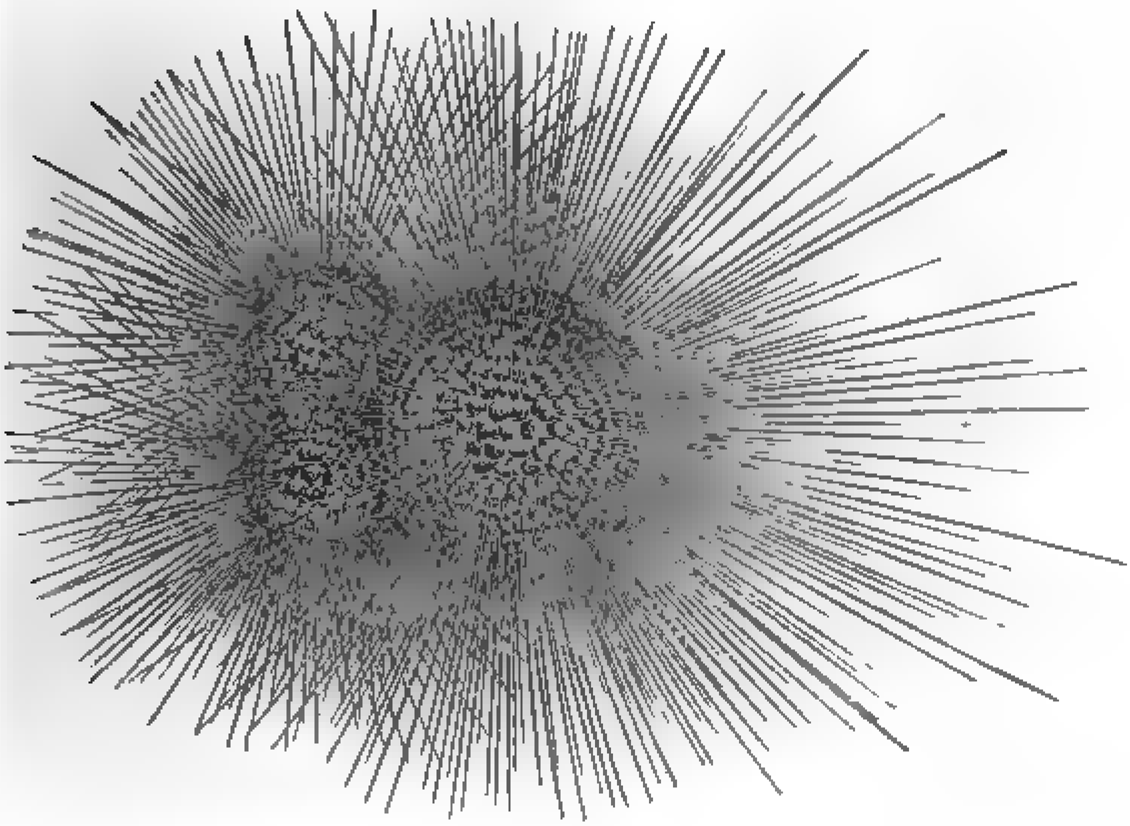

FIG. 40. Globigerina (magnified 100 times)

varied by hills and valleys such as occur on the lands. A large part of the deep sea bottom is covered with a fine deposit, called ooze, which consists of the minute shells, more or less decayed, of simple animal forms that live at or near the surface. One of these, highly magnified, is shown in Figure 40. In the deepest oceans the bottom is covered with a fine reddish clay. Nearer the shores

the deposits become muddy with sediments derived from the land. It is by the very slow but long-continued accumulation of these deposits that the ocean floor has been made so smooth.

"The monotony, dreariness, and desolation of the deeper parts of this submarine scenery can scarcely be realized. The most barren terrestrial districts must seem diversified when compared with the vast expanse of ooze which covers the deeper parts of the ocean."

No mountain ranges with sharp peaks and ridges separated by deep passes and valleys have yet been discovered on the open ocean floor far from the continents; but Cuba and some of the neighboring islands in the West Indies seem to be the crests of a mountain range whose western extension forms submarine ridges in the northern Caribbean, connecting the islands with Central America.

Volcanic and coral islands rise with steep slopes from the deep ocean. Volcanic cones sometimes rise above the ocean surface, forming lofty mountains, as in the Hawaiian islands; sometimes they are known only by soundings, their summits being below sea level.

77. Mediterraneans. — Besides the open oceans thus far considered there are several deep seas, more or less separated from the oceans by land barriers. The most important of these is the classic Mediterranean (the sea "in the middle of the lands"); its average depth is nearly as great as that of the great oceans, but it is connected with the Atlantic only by the narrow and shallow Strait of Gibraltar.

Other similar mediterranean seas are the Caribbean and the Mexican (deep central part of the Gulf of Mexico), adjoining the western Atlantic; and the Japan, China, Sulu, and some smaller seas imperfectly inclosed from the western Pacific by island chains. The deep water of mediterraneans is warmer than that of the neighboring oceans, whose cold bottom waters cannot enter the inclosed basins.

78. Continental Shelves. — The ocean often overlaps the borders of the continental masses in a comparatively shallow belt of water, at whose outer edge the depth is commonly about 600 feet; thence it rapidly sinks to the deep ocean floor. These shallow bottoms are known as continental shelves. The water on the shelf is often greenish from fine suspended sediment, unlike the clear deep blue water of the open ocean.

A well-defined continental shelf, from 50 to 100 or more miles in width, stretches along the eastern side of North America from Newfoundland to Florida, and thence around the Gulf of Mexico. The British Isles stand upon a continental shelf that borders mid-western Europe. The Malayan and Australasian islands surmount broad shelves between Asia and Australia, separated by a belt of deeper water.

The gravel, sand, and clay washed from the lands into the seas are moved about by waves, currents, and tides on the continental shelves. Thus the land waste is slowly ground finer and finer, and its finest particles are gradually moved outward to deeper water. They are seldom

found in dredgings over 200 miles from shore; for the most part they are carried a less distance.

In the course of years, centuries, and ages the sediments thus accumulating on a continental shelf may form successive layers, each a few inches or feet in thickness, according to the rate of supply. A layer of sediments of this kind is called a bed or stratum (plural, strata). Many strata laid down on the sea floor, one

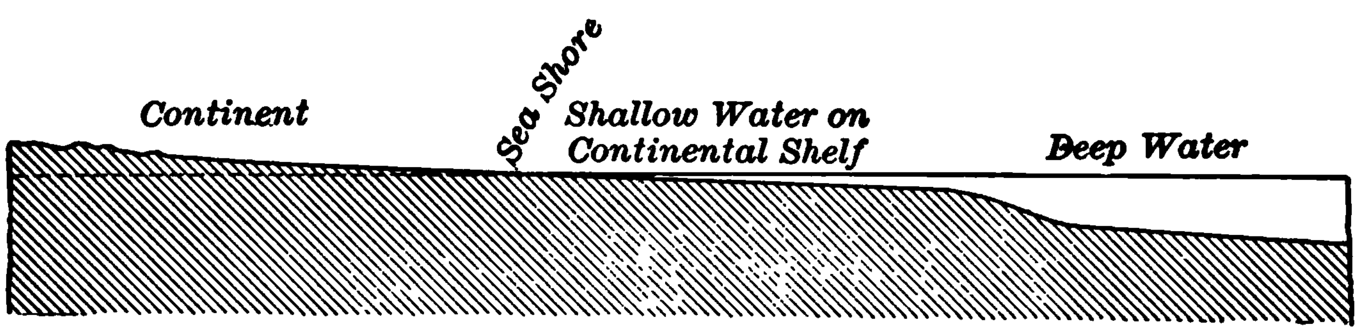

FIG. 41. Section of Continental Shelf

after another, may form a heavy deposit hundreds of feet in thickness, including many shells and other relics of marine life.

As new strata are added, the older strata are buried deeper and deeper, their grains are more or less cemented together by mineral substances deposited upon them by slowly infiltrating waters, and thus they gain a firm texture. It is chiefly in this way that layers of loose sediments are changed into layers of solid rock.

The lowland borders of continents are often built of layers of sand and clay frequently containing marine fossils; this suggests that a former continental shelf has there been raised to a land surface.

The shallower waters of continental shelves are of great importance as the chief fishing grounds of the

world. The European ports around the North sea send out hundreds of fishing vessels to its shallow waters. The rich fishing grounds of the Newfoundland banks attracted many fishermen from the Old World over three centuries ago. They are still resorted to every year by fishermen from New England, chiefly from Gloucester, Massachusetts. Although far out of sight of land, the water on the banks

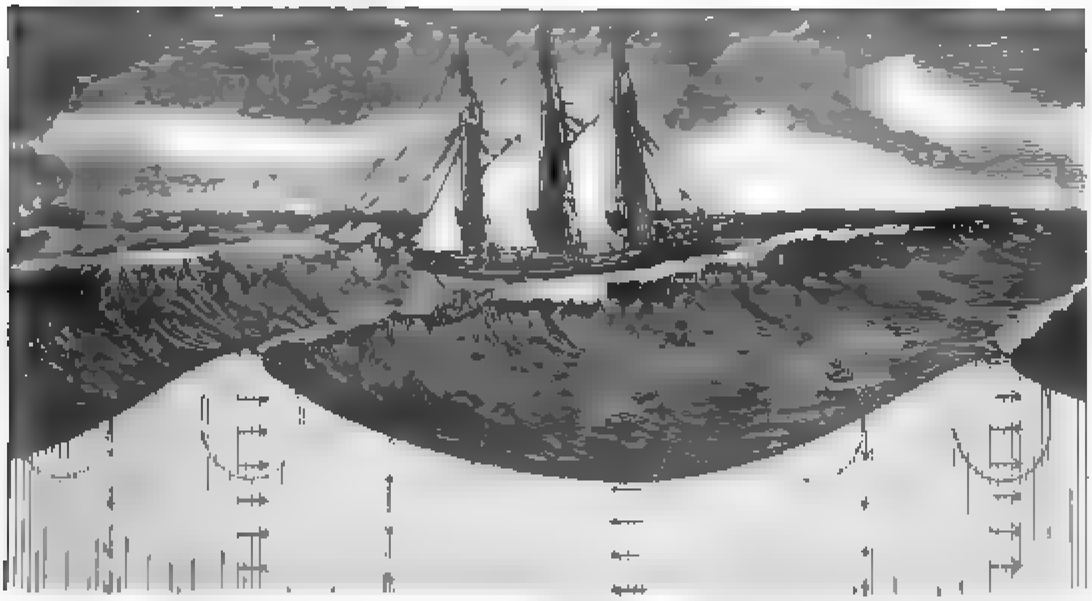

Fig. 42. Orbital Movement of Water in Waves

is so shallow that fishing schooners (such as the one shown in Figure 42) may ride at anchor while their men go off in small boats to fish with nets or with hook and line. During fogs, which are frequent, there is danger of collision with transatlantic steamers, whose route leads them through the fishing grounds.

79. Waves.—Wind blowing over the sea forms waves that follow the wind. The water in the waves moves only up and down, back and forth, with very small forward motion. The

stronger the wind, the higher the crests and the deeper the troughs of the waves, the greater their length (distance from crest to crest), and the faster their forward motion.

The waving of a field of grain under the wind may be taken as an illustration to show the relation of the curved-path movement of the particles to the forward progress of the waves. The independence of wave and water movement may be seen on a river surface when the wind is blowing upstream ; or at the mouth of a harbor when the wind is blowing on shore, while the tide is running out.

Great waves formed in the open ocean by gales and hurricanes are often called seas. Their height from trough to crest reaches 30 or 40 feet, but seldom exceeds 50 feet. Their length varies from 300 to 1500 feet or more, and their velocity from 20 to 60 miles an hour. The interval between the passage of successive crests, or the period of the wave, is seldom more than 10 or 12 seconds.

80. The Use of Oil in Storms. — A small quantity of oil poured on the sea spreads rapidly and reduces the violence of the waves in a storm. A gale ordinarily forms ripples and small waves on the backs of greater waves and causes the crests of great seas to curl over, so that they would break with destructive force on the deck of a vessel. At such a time a film of oil decreases the catch of the wind on the water and prevents the large waves from curling and breaking.

Many accounts of the use of oil in storms have been published by the United States Hydrographic Office, Washington. They show that when a vessel is headed

toward the wind ("hove to") and heavy seas come on board over the bow, a little oil allowed to drip from a bag will spread even toward the wind, forming a smooth surface, or "slick," and the waves entering the slick will decrease in height and cease breaking over the deck.

When a vessel is running with the wind heavy seas sometimes come aboard over the stern; but if a little oil is allowed to drip overboard, the slick spreads out like a fan across the wake, and the great seas are rounded off as they run into it, so that the vessel rides them without difficulty.

81. Swell and Surf. — Great waves, traveling twenty to sixty miles an hour, soon run out of the storm that forms them and swing far across the ocean, preserving their length and velocity, but diminishing in height. In this reduced form a wave is called a swell.

In calm weather the ocean surface may be smooth and glassy, but not absolutely level and quiet; for it is never free from the slow heaving and sinking of fading swells from distant storms. A vessel becalmed in the doldrums always swings idly to and fro as the swell rolls by.

When the swell runs into shoaling water close to land its velocity decreases, its crest rises and its trough sinks, thus making its height greater; the front becomes steeper than the back. The swell thus becomes higher and higher as it advances. If it arrives on a long, smooth, gently sloping beach, the water before the advancing wave becomes so shallow that it cannot build up the wave front; then the crest curls evenly forward in long lines nearly parallel

with the shore and dashes with a roaring noise upon the beach, in the form of surf or breakers.

The surf is like a mill in which cobbles, gravel, and sand on a beach are ground finer and finer. The pebbles can be heard rattling as they are rolled back and forth.

Fig. 43. Surf

Exposed beaches may be beaten by a heavy surf, ten or fifteen feet high, while the neighboring sea is unruffled by the wind. The surf is then derived from a broad swell which comes from the great waves of a storm that may be a thousand or more miles away.

The great hurricane of Sept. 3–12, 1889, while on its way from the West Indies to the Carolina coast, produced a destructive surf on the long beaches of New Jersey while the storm area was still a thousand miles distant. At St. Helena,

a lonesome island in the South Atlantic, boats from vessels at anchor in the harbor frequently cannot reach the shore in fair weather on account of the "rollers," or heavy surf, on the beach. The swell that produces this surf is believed to come from storms far away in temperate latitudes of the North Atlantic.

When waves run upon a steep and rocky shore they dash unevenly against the ledges, foaming and fretting as they sweep back and forth. During storms spray may be flung up 50 or 100 feet into the air. These great waves exert an enormous force, capable of moving blocks of rock ten or more feet in diameter. Wave work is not then limited to the immediate shore line; loose materials in depths of ten, twenty, or more fathoms are moved about and ground smaller and smaller, and the finest grindings are swept away to deeper, quieter water.

82. Earthquake Waves. — When an earthquake, caused by some disturbance in the earth's crust, occurs beneath the sea the whole body of the ocean above it is moved slightly, and the movement then spreads away on all sides in long, low waves that travel with great speed. When nearing the shore the speed and length of the wave are decreased, but the height is greatly increased. The wave may then rush far in on a lowland coast, causing great destruction.

The tremendous explosive eruption of the volcanic island Krakatoa, between Java and Sumatra, in August, 1883, produced waves that spread far around the world. Their average velocity of progression was nearly 400 miles

an hour. On distant coasts their rise and fall was slight, but on coasts near Krakatoa the waves rushed upon the land with a height of from fifty to eighty feet, flooding the lowlands, sweeping away many villages, and drowning thousands of the inhabitants. A large vessel was carried a mile and a half inland and stranded thirty feet above sea level.

An earthquake in the North Pacific produced a destructive wave, from ten to fifty or more feet high, on the coast of northern Japan in the evening of June 15, 1896. The coast was laid waste for 175 miles. The few persons who saw the wave and survived it reported that the sea first drew back about a quarter of a mile and then came rushing in like a black wall, gleaming with phosphorescent light and overwhelming the shore. On the open coast the sea became quiet in a few minutes after the wave broke, but in bays the waters surged and swirled for half an hour. The outline of the shore was changed in many places; many villages were destroyed, and thousands of acres of arable land were laid waste. Thousands of fishing boats were crushed or carried away; 27,000 persons lost their lives, and 60,000 survivors were left homeless.

83. Ocean Currents. — The upper waters of the ocean, to a depth of 50 or 100 fathoms, move slowly in the general direction of the prevalent winds, thus forming currents that circulate about the great oceanic areas. The general course of the ocean currents is such that each of the large oceans possesses a great eddylike current that moves slowly around it, leaving the central waters almost quiet.

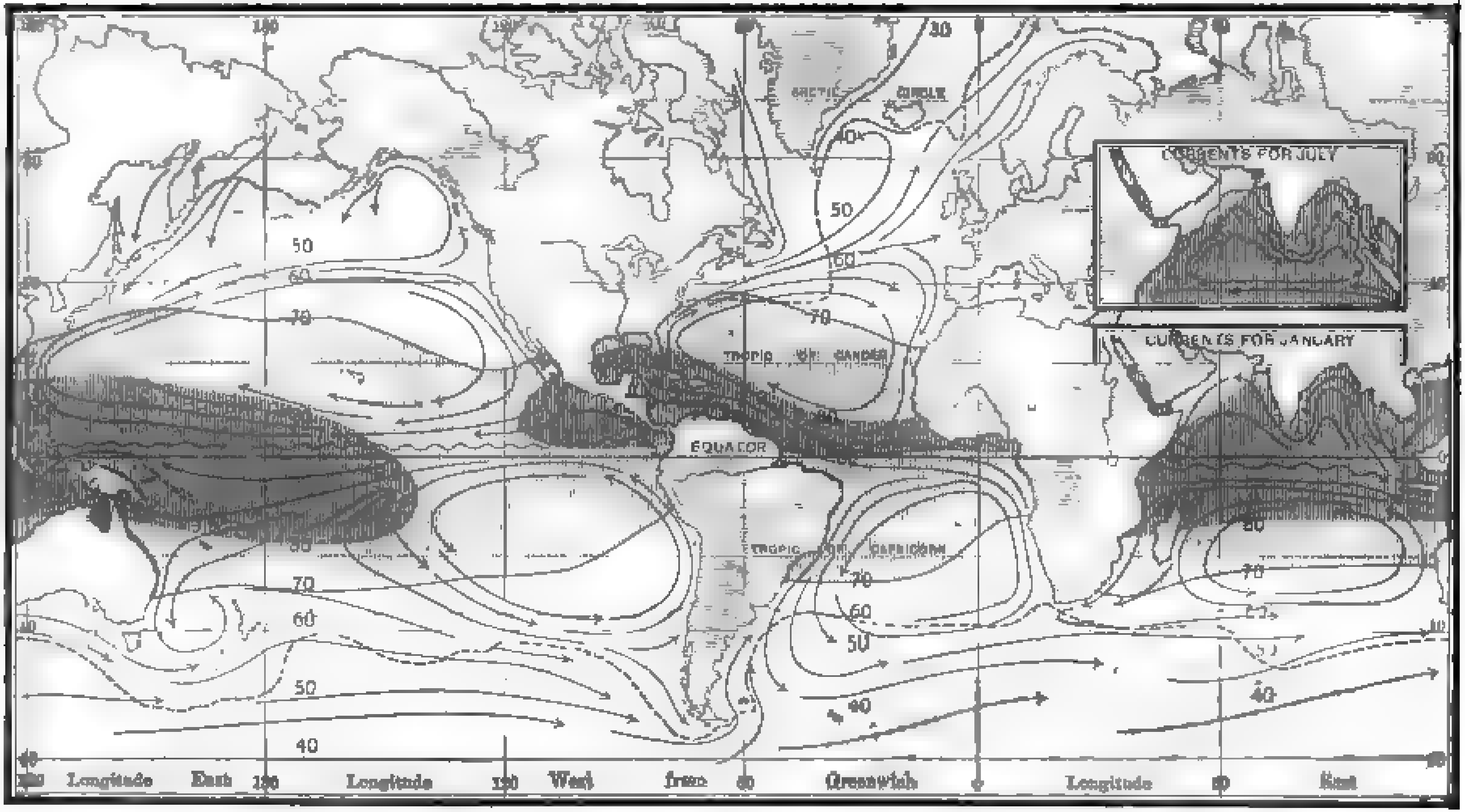

Fig. 44. Chart of Ocean Surface, Temperatures, and Currents. Broken lines, limits of floating ice

Exercise. How many systems of eddying currents are shown in Figure 44? Which one is the largest? Which three smaller ones are of about the same size? In what ways are the eddying currents alike? In what different? Compare their movements along the west coasts in middle latitudes; along east coasts. How do they move near the equator? Note the long equatorial countercurrent in the Pacific, separating the two great eddies, north and south. Note the connecting current between the two eddies of the Atlantic. Compare the general courses of the winds, Figures 22 and 23, with the courses of the ocean currents. Name some districts where the winds and currents agree.

The remarkable correspondence between the course of the oceanic eddies, Figure 44, and the course of the prevailing winds over the oceans, as shown in the charts, Figures 22 and 23, points to the winds as the cause of the currents. Like the circulation of the atmosphere, the eddying of the upper waters of the oceans must be regarded as a characteristic of a globe having large oceans, a mobile atmosphere, and a warm equatorial zone.

The belief that the winds cause the currents is confirmed by the way in which the surface drift of the waters may be for a time brushed to one side of its usual course, or even reversed, during a storm.

If an observer stood in the center of an oceanic eddy in the northern hemisphere, the currents would pass around him from left to right, or clockwise; in the southern hemisphere, from right to left, or counter-clockwise.

The eddying currents are the chief natural basis for subdividing the great oceanic area into the six oceans; the North and South Pacific, the North and South Atlantic, and the Indian oceans each having its own great eddy,

while the Antarctic ocean has a great eddy around the south pole, joining the eddies of the three southern oceans. The Arctic also has a current about the pole joining that of the North Atlantic, somewhat like the two loops of a figure 8; but the Arctic should be classified as a large sea or gulf rather than as an ocean.

A broad and shallow current that advances at a rate of ten or fifteen miles a day, like that which crosses the middle North Atlantic, should be called a *drift*. A narrow current, flowing with a velocity of fifty or more miles a day, like that issuing from the Gulf of Mexico through the Strait of Florida, should be called a *stream*.

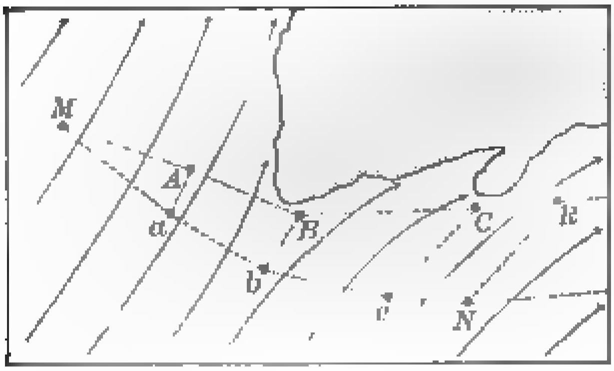

FIG. 45. Displacement of a Vessel by Currents

It is important that the masters of vessels should be acquainted with the movements of ocean currents. In cloudy and foggy weather, when observations of the sun cannot be made to determine latitude and longitude, a vessel might be drifted out of its expected course if no allowance were made for the movement of the waters. Thus, if a vessel intending to follow the course *MabcN*, Figure 45, were drifted to the course *MABCR*, it would pass dangerously near the headlands at *B* and *C*, and might even run ashore. Wrecks on the southwest coast of Ireland have not infrequently been due to this cause.

In Nansen's famous attempt to reach the north pole he sailed eastward along the northern coast of Asia and turned northward into a region of ice fields, where his vessel was caught between two floes. He then drifted with the ice, expecting that the Arctic current would carry him past the pole toward Greenland. Had he gone further east before turning north, a closer approach to the pole might have been made.

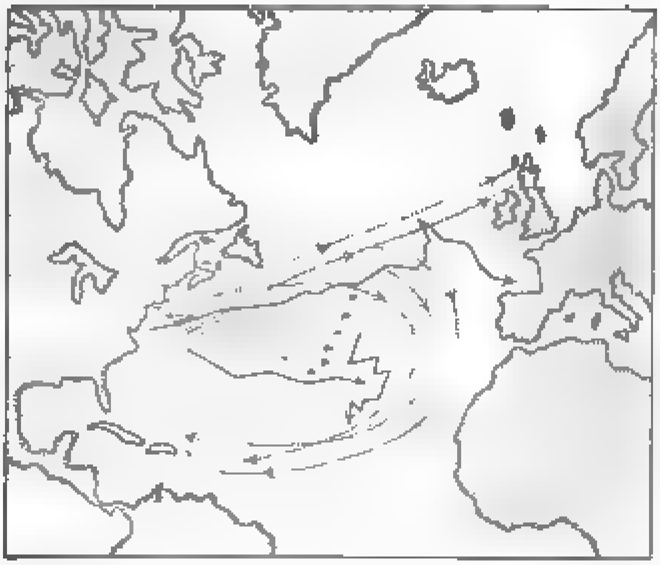

FIG. 46. Drift of Floating Objects by Currents

The drift of abandoned wrecks, whose positions are noted by passing vessels, gives indications of the movements of currents. The angular lines in Figure 46 show the drift of several wrecks. The broken lines indicate the drift of many logs from a great timber raft that was abandoned in a storm while on the way from the Canadian provinces to New York, December, 1887.

Thousands of bottles have been thrown into the sea, with record of the time and place where they have been set adrift and request that the finder shall report the time and place of their discovery, afloat or ashore. The dotted lines of Figure 46 give a few inferred "bottle tracks."

The several parts of the various eddies may receive special names. Those parts which run westward, near and

about parallel to the equator, are called the equatorial currents. The eastern part of the South Pacific eddy is called the Humboldt, or Peruvian, current; it brings a great body of cool water from far southern latitudes.

The name Gulf Stream, in the Atlantic, should be limited to the narrow, deep, and rapid current which issues from the Gulf of Mexico with a velocity of eighty miles a day; the name is popularly, but incorrectly, extended far northeast over the broad, shallow, and slow-moving drift on the northern side of the North Atlantic eddy, and even along its branch, past Norway. This extension of the current is not a stream at all, and it includes much water that passed outside of the West Indies and not through the Gulf of Mexico.

Sailing vessels should take advantage of winds and currents in shaping their courses. If bound from the eastern United States to far South American ports, they should cross the equator well to the eastward, so as to avoid being carried backward by a strong current past the Guiana coast, where the winds may fail in the doldrums. A ship sailing from an Atlantic port to Australia should round Cape of Good Hope and take advantage of favorable winds and currents in the southern Indian ocean about latitude 50°. On the homeward voyage favoring winds and currents would be found in the same latitude of the South Pacific, toward Cape Horn.

84. Currents and Temperatures. — Currents influence the distribution of temperature in the oceans and in the winds that blow over them. In the North Atlantic, for

example, a broad drift of rather warm water flows northeast in middle latitudes, past the British Isles and Norway; while a cold current returning from the Arctic regions flows southward past Labrador and Newfoundland. Hence, in the same latitude, winds from the sea are mild in northwestern Europe and chilling in northeastern America.

In winter the harbors of the Labrador and Greenland coast are closed with ice; harbors in the same latitude on the eastern side of the Atlantic remain open all the year round. In what countries are these harbors situated? Northern Norway has a milder climate than any other country at so great a distance from the equator. Why is this? What land in the southern hemisphere is as far from the equator as Norway?

The southern coast of Alaska has a comparatively mild climate on account of the northeastward drift of the surface waters in the North Pacific eddy. The cool Peruvian current keeps the temperature so low about the Galapagos islands (near the equator west of Peru) that coral reefs, such as abound further west in the equatorial Pacific, are not found on their shore.

85. Tides. — Regular movements of the ocean, rising and falling on the shores twice in a little more than a day (twenty-four hours, fifty-two minutes), are called tides. In the open ocean tides are not perceived; but in many bays the tidal change of level, or range, reaches ten, twenty, or more feet. The highest stage of the tide is called high tide or high water; the lowest stage, low tide or low water. The change of level is accompanied by currents, — flood tide

running in from the ocean, ebb tide running out again. A brief period of quiet, or "slack water," occurs when flood changes to ebb, or ebb to flood. The vessels that are aground at low tide in Figure 47 would be afloat at high tide.

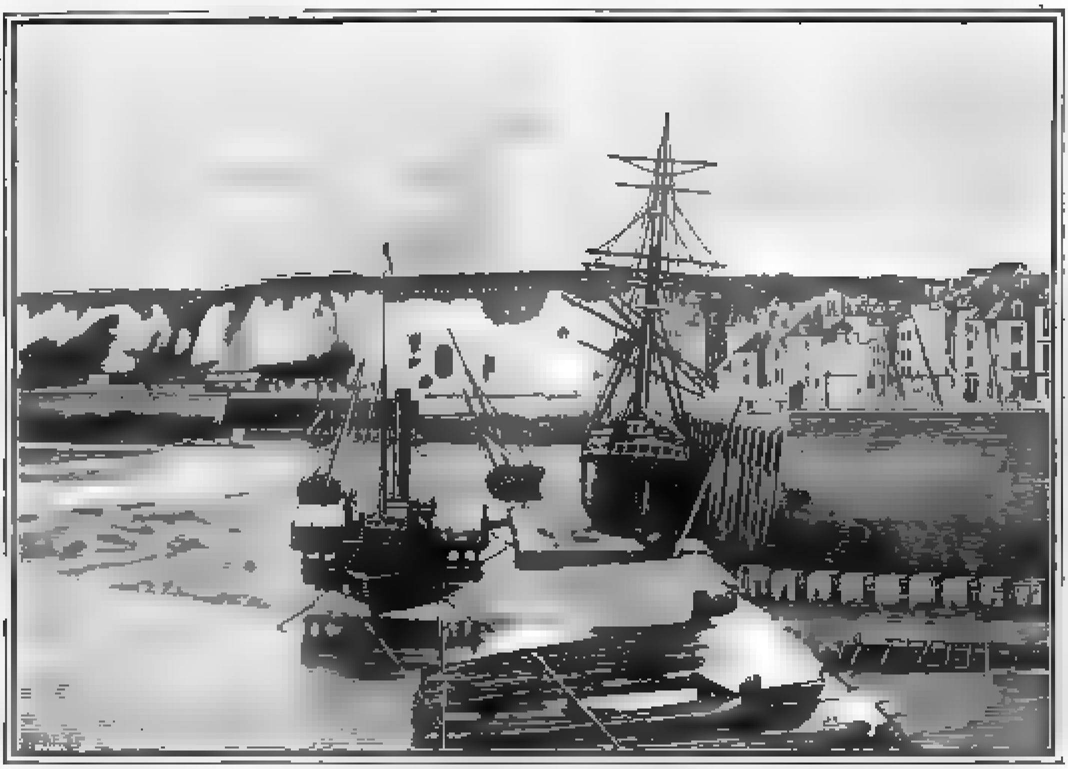

FIG. 47. Low Tide in a Harbor

The tidal undulations of the oceans are caused chiefly by the attraction of the moon; they are somewhat affected by the attraction of the sun.

Tidal currents are beneficial in maintaining a circulation in bays and harbors where the waters might otherwise be almost stagnant. At high water a harbor will admit vessels of a larger size than could enter if the ocean level did not change; but at low water the harbor may be inaccessible except to much smaller vessels. The hour of departure of ocean steamers is usually determined by the

Plate V. The Bore, or Surf-Like Flood Tide, in an Estuary at the Head of the Bay of Fundy, Nova Scotia

hour of high tide, so that they may have water as deep as possible when leaving their harbor.

In funnel-shaped bays or estuaries the tidal range becomes large, and flood and ebb currents are very strong, making navigation difficult or even dangerous. The tidal range sometimes exceeds fifty feet in the estuaries at the head of the Bristol channel in western England, and of the Bay of Fundy in Nova Scotia; in the latter the flood

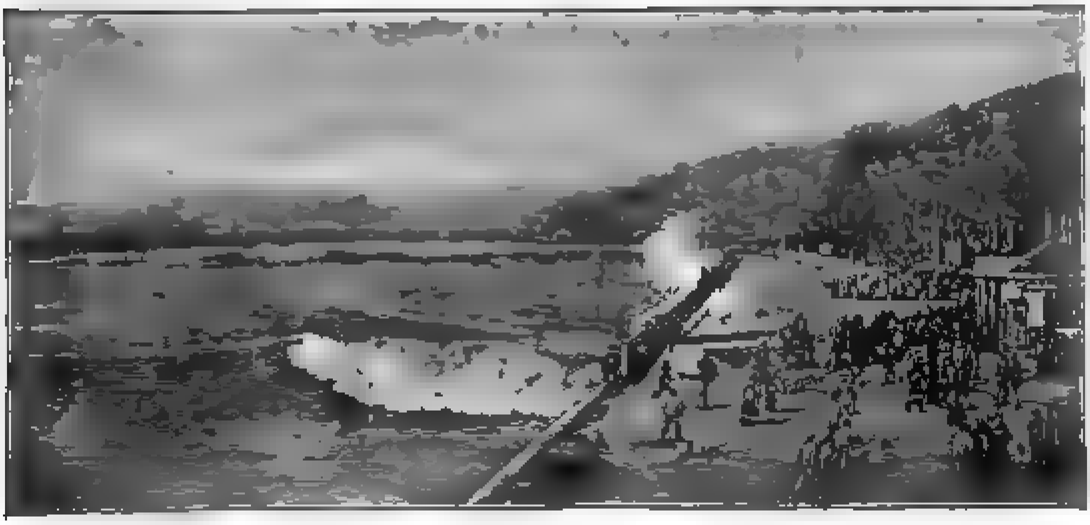

FIG. 48. The Tidal Wave, or Bore, in the Seine

current rushes in like foaming surf, shown in Plate V. The estuary of the Seine in northwestern France has a similar surf-like tide, shown in Figure 48. Such surf-like tides are called bores. A bore occurs at the mouth of the Amazon; it is so violent on the northern side of the river near the sea that the shore line is rapidly worn back, and hence no important settlements have been made there.

Where tidal currents are thus strengthened they sweep the sediments of the shallow bottom back and forth, grinding them finer and finer. The finest particles thus

produced are slowly drifted offshore, where they settle in deep water. When a gale is blowing and producing waves in strong flood or ebb currents their work on the bottom is much increased; for the sediments are slightly raised from thè bottom by the agitation of the waves, and thus they are brought more into the power of the tidal currents.

Fig. 40 Jellyfish floating in Sea Water

Many curious tidal phenomena are found on shore lines of different forms. At New York a high tide entering from the harbor reaches the rocky narrows of Hell Gate when a low tide arrives through Long Island sound; and six hours later a low tide from the harbor meets a high tide from the sound. Thus a rapid current is caused to flow back and forth in the narrow passage, which was dangerous to vessels until the channel was widened by blasting away its reefs. A current of this kind is sometimes called a tidal race.

86. Life in the Ocean. — The surface layers of the open ocean possess a considerable variety of animal life, from [illegible]ge mammals, like whales, to minute organisms, Figure [illegible] whose tiny shells are so plentifully strewn over the

ocean floor. The former occur in moderate numbers; the latter are countless. The distribution of surface life is determined chiefly by differences of temperature from the torrid to the frigid zones. Those forms which swim or are drifted freely by the currents are found over vast areas. In fair weather the surface waters are sometimes alive with minute jellylike forms.

FIG. 50. Deep-Sea Fish. × ⅓

The nearly quiet water about the central part of the great eddying currents generally contains a considerable quantity of floating seaweed, or *sargassum;* hence these central areas are called sargasso seas. The *sargassum* is believed to be derived from shore waters, where it grows on the shallow bottom. A great variety of small animals live on the floating weed, and a certain kind of fish uses the weed as a "nest" for its eggs.

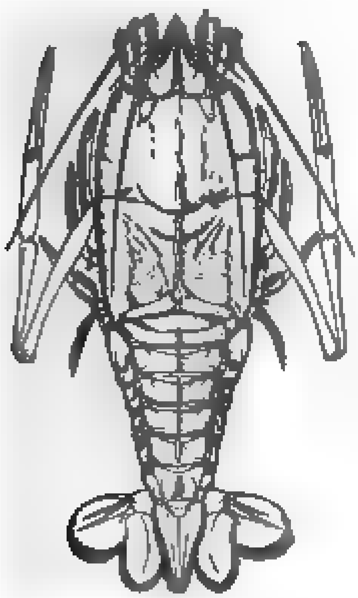

FIG. 51
Deep-Sea Crustacean. × ½

The intermediate depths of the ocean, between the upper part and the bottom, are prevailingly without life, — a great desert space, cold, quiet, and monotonous.

The deep ocean floors have no plants. They are inhabited by a considerable variety of animals, such as fish, crabs, shellfish, starfish, etc.; but the forms of life are

here much less varied and less numerous than in the shallower waters near the shore.

While many deep-sea animals are blind, it is curious that some have well-formed eyes and are ornamented with colors. Colors would be useless if they could not be seen, and eyes would be of no service in complete darkness. Hence there must be some light in the ocean abysses. As sunlight cannot penetrate to great depths, the light may be supplied by phosphorescent animals, of which there are many kinds in the deep sea.

The shallow waters of the ocean margin teem with plants and animals. Many animals, such as sponges, corals, and barnacles, are fixed to the bottom; they need not move about in search of food, because the moving waters bring it to them. Nearly all the plants of the sea are of a comparatively simple kind, without flowers or seeds. The shallow waters are the fishing grounds of the sea and furnish important supplies of food to the neighboring lands.

Supplement to Chapter III

87. The Cause of the Tides. — Note the time when the moon passes over the south point of the horizon on two successive days. (These observations may be made in the early evening when the moon is near its first quarter. If daytime observations are preferred, they may be made in the early forenoon when the moon is between third quarter and new; or in the late afternoon between new moon and first quarter.) How long is the interval between the two passages? Compare this interval with that between two high tides, as stated on page 119. How are the two intervals related?

The above comparison shows that the tides in some way depend on the moon, because two sets of tides occur in the time (24 hours

52 minutes) between two successive passages of the moon across the meridian. It can be shown that the attraction of the moon on the oceans tends to cause high tides, H' and H'', Figure 52, on opposite sides of the earth near the equator, with low tides, O' and O'', between them. The tides tend to preserve a constant position with respect to the moon, somewhat as indicated in the figure. Hence as the earth turns round (the axis standing at right angles to the paper), any point in the equatorial oceans must pass H', O', H'', O'' in 24 hours 52 minutes, and must therefore experience two high and two low tides in that period. The moon tends to form similar but weaker tides around all the latitude circles in the two hemispheres.

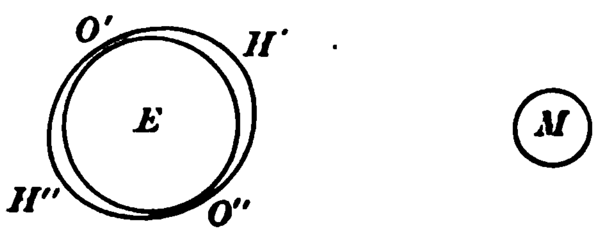

FIG. 52

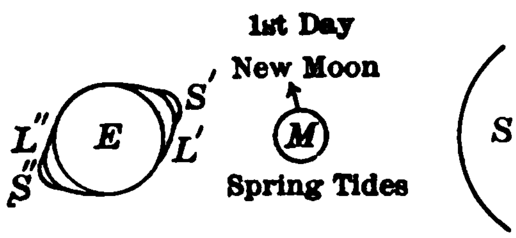

FIG. 53

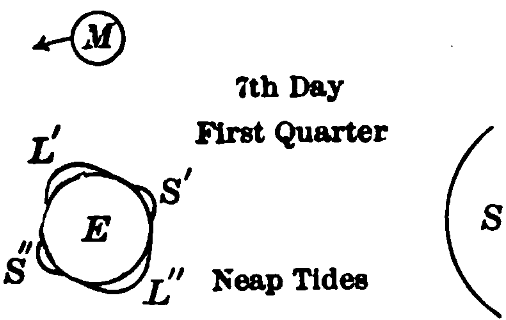

FIG. 54

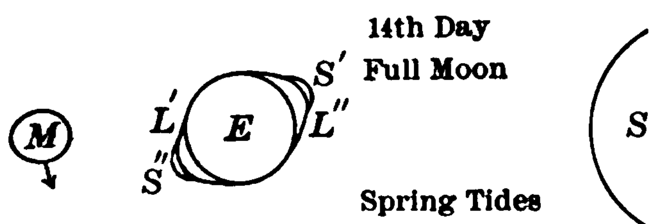

FIG. 55

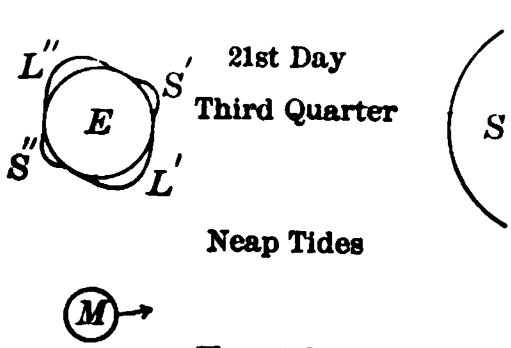

FIG. 56

The sun also tends to cause tides; but in spite of the vastly greater size of the sun than of the moon, the sun is so much farther away that the solar (sun) tides have only about one third of the strength of the lunar (moon) tides.

At new moon, when the sun and moon are on the same side of the earth, as in Figure 53, the lunar (L) and solar (S) tides act together, and hence the rise and fall of the tides, or the tidal range, is increased. At first quarter the line to the moon is at right angles to that to the sun, as in Figure 54. Here the sun tries to make a low tide where the moon makes a high tide, L; and the moon makes a low tide where

the sun tries to make a high tide, *S*. As a result, the tidal range is weakened. How do the lunar and solar tides combine at time of full moon, Figure 55? at time of third quarter, Figure 56?

It thus appears that in the twenty-eight days between two new moons, or about a month, the tidal range is strong, weak, strong, and weak. At the times of strong range the tides are called spring tides; at times of weak range, neap tides. The variation of tidal range from new moon to full moon is shown in Figure 57. How often does the period of spring tides occur in a month? of neap tides?

It is not possible at present to state how the tides behave in the open ocean; they cannot be observed in deep water, far from shore.

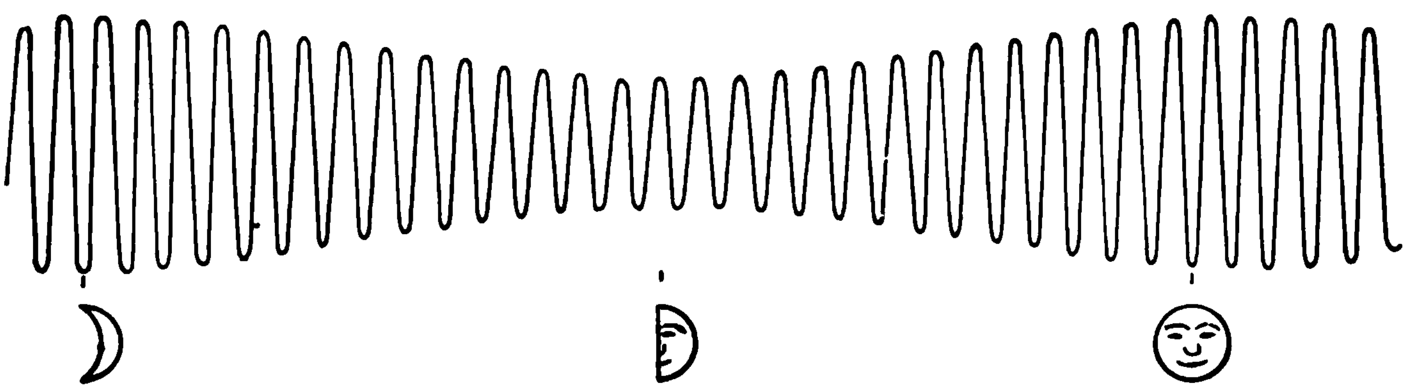

FIG. 57. Variation of Tides for Two Weeks

They are known only as they come upon the shores of islands and continents. Their strength then depends not only on the combination of lunar and solar forces, as in spring tides and neap tides, but still more on the form of the shallowing sea floor and of the shore line. Just as swell is increased in height as it runs ashore, so are the tides; for the tides are in reality very long, low waves; but while the surf caused by the arrival of successive swells may roll in on a beach every five or ten seconds, the high tide rolls in only every 12 hours 26 minutes. Its strength is usually less on headlands than in bay heads.

QUESTIONS

Secs. 68, 69. What is the ocean? Compare the Arctic and Antarctic oceans. Locate the poles of the land and water hemispheres. Consider the ocean as a highway.

70, 71. Compare the earlier and later objects of ocean exploration. Describe the method of deep sounding. What is a water bottle? a dredge? How are nets used in sounding? Where are the places of greatest depth in the ocean? About how deep are they?

72, 73. What mineral substances are dissolved in ocean water? What is their source? What gases are dissolved in ocean water? What purpose does one of these gases serve? What is the density of ocean water? What amount of dissolved substances does it contain? Compare the ocean and the atmosphere. Describe the colors of the ocean under different conditions. What causes phosphorescence?

74. Describe the distribution of temperature at the ocean surface; at the ocean bottom. How do ocean temperatures vary through the year? How deep does sunshine penetrate the ocean? Compare the effect of changing temperature on the density of fresh water; of salt water. How is the cold water at the bottom of the equatorial oceans accounted for?

75. Why does ice float? What is floe ice? pack ice? What are icebergs? What size do they reach? How do they float? Where are they seen? What is their source?

76. Describe the deep ocean bottom. What is the character and source of ocean-bottom materials? What can you say of mountains and volcanoes in the ocean?

77. What is a mediterranean? Name the chief examples. How does their temperature differ from that of the oceans?

78. What is a continental shelf? Give some examples. What materials are found on continental shelves? How are stratified deposits formed? What do they include? How may they be changed to rock? Of what value to man are the shallow waters of continental shelves?

79, 80. What are waves? What size do they reach? How do they move? Illustrate the difference of wave movement and water movement. What effect has oil on waves?

81, 82. What changes of form do waves suffer? What is swell? surf? Why does surf fall forward? What are "rollers"? What work is done by waves? To what depth may they act? What is an earthquake wave? Describe two examples.

83. What are ocean currents? What is their general movement? What divisions of the ocean are suggested by its eddying currents? What is a drift? a stream? Of what practical importance is a knowledge of ocean currents? How are ocean currents determined? What is the cause of ocean currents? How is this proved? Name and describe some important members of the oceanic eddies. To what should the name Gulf Stream be limited? How may sailing vessels take advantage of winds and currents?

84. How do ocean currents influence the distribution of temperature? Give examples from Labrador, Great Britain, Alaska, Peru.

85. What are the tides? Define high tide, low tide, slack water, flood, ebb. How are tides caused? What practical benefits arise from them? What inconveniences? What is tidal range? What may it amount to? Where does strong range occur? What is a tidal bore? What work is done by tidal currents? When is this work most effective? What is a tidal race? Give an example.

86. Consider the distribution of life in the ocean surface waters. How is it chiefly controlled? What is a sargasso sea? What can you say about the intermediate depths? the bottom? What can be inferred from the color and eyes of deep-sea animals? Consider the distribution of life in the shallow marginal waters.

CHAPTER IV

THE LANDS

88. Area of the Lands. — The globular earth is uneven enough to raise somewhat more than a quarter of its surface slightly above the oceans in broad land areas, called continents.

The area of the globe is about 197,000,000 square miles. The lands occupy somewhat more than 50,000,000 square miles; their total area remains uncertain until the polar regions are fully explored. Six sevenths of the land area are in the land hemisphere (see Figure 34), where the ocean occupies little more than half the surface. The lands in the water hemisphere occupy only about one fifteenth of the surface.

89. The Continents. — There are five large bodies of land, known as continents. Europe and Asia together form a single continent, often called Eurasia, the largest of the five. On account of the great extent of this continent, and still more because of its varied relations to human history, it is convenient to describe both Europe and Asia as a "grand division" of land.

The other continents are Africa, North and South America, and Australia, the last being the smallest of the five. It is possible that the lands of the Antarctic

regions may be discovered to be large enough to rank as a continent; but little is known of them at present.

The five continents differ greatly in size, outline, arrangement of parts, and degree of separation. The most remarkable fact concerning their distribution over the earth's surface is that they cluster around the Arctic circle, inclosing the Arctic ocean, and thence extend far southward, narrowing toward their ends in the great ocean of the southern hemisphere. The narrow North Atlantic and the much narrower Bering strait occupy only about one ninth of the Arctic circle; the rest of its circuit crosses the lands, with a few narrow arms of the sea that separate some of the Arctic islands from North America.

South America lies southward of North America; Africa lies southward of western Eurasia; Australia lies southward of eastern Eurasia. None of these southern continents reach the parallel of 60° south latitude; the whole circuit of this parallel lies on the ocean.

Another remarkable feature in the distribution of the lands is that two land areas are seldom found opposite to each other, on opposite sides of the earth. Opposed to each continent is generally an ocean surface, as may be seen by examining a globe.

A third remarkable feature regarding the distribution of the lands is that, excepting Australia and the possible Antarctic continent, nearly all the other lands are found on one half of the earth's surface, known as the land hemisphere. (See page 96.)

Eurasia and Africa are often called the Old World, because parts of them have been known to the people of

our race for more than twenty centuries; while North and South America are called the New World, because they have been known to us for only a little more than five centuries. But these names are appropriate only from the point of view of human history. Both the Old and the New Worlds, so called, contain so much very ancient land, raised above the ocean in early stages of the earth's history, and so many mountains and plains that have been formed in the later stages of the earth's history, that neither world should be regarded as, on the whole, older or younger than the other.

The greatest islands are comparatively near the continents, as in the archipelago north of North America, the West Indies, Newfoundland, the British Isles, Madagascar, the Japanese islands, the Malayan-Australasian archipelago, and New Zealand. Most of these islands stand upon continental shelves and are separated from the continents only by comparatively shallow water; but New Zealand is separated from Australia by deep water. The numerous oceanic islands, distant from continents, are of small total area (about 40,000 square miles).

90. Height of the Lands.—The highest mountain peaks (25,000 to 29,000 feet) do not rise above sea level so much as the greatest ocean depths sink below it (31,600 feet). The average elevation of the lands (2400 feet, less than half a mile) is much less than the average depth of the oceans (about two miles).

Figure 58 exhibits the proportion of high and low land, and of deep and shallow ocean, the whole area of the earth

being measured by the breadth of the figure. It is thus seen that most of the land surface is but little above sea level, while most of the sea floor lies deep below the sea surface.

91. Changes of Continental Outline. — The form of the lands and the outline of their shores seem at first sight to be unchangeable. But the more the world is studied, the more certain it becomes that very slow movements are going on in the earth's crust, and that the outline of the continents is subject to change as the continental masses very slowly rise or sink. The movements are so slow that they are hardly perceptible in the course of a century; but when continued for hundreds of centuries they cause changes of great importance in the geography of the lands.

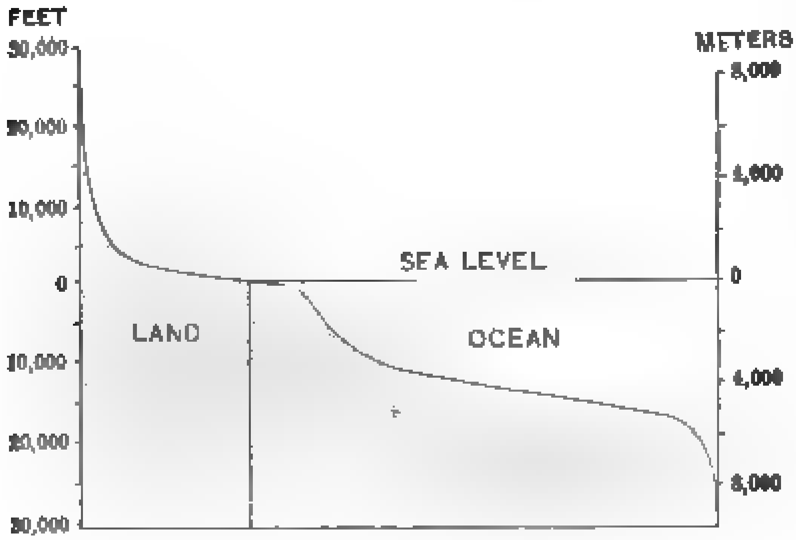

Fig. 58. Height of Land and Depth of Sea

Observations in the last hundred years or more give reason to believe that the coasts of Massachusetts and New Jersey are now sinking (one or two feet a century), and that much of the coast of Sweden is rising (greatest rise, three feet a century). The coast of the Netherlands is sinking a foot a century, and its fields near the shore, fifteen to twenty feet below the sea level, are diked to keep

the water off. Canada northeast of the Great lakes is rising, so that the waters of the lakes are slowly backing up on their southwestern shores.

Widespread layers of rock containing fossils of sea animals are found on various parts of the continents, showing that these parts of the lands have, in some ancient time, been beneath the sea. Many other proofs of change of level will be given on later pages.

92. Varied Conditions on the Land Surface.—The surface of the continents possesses great variety of form and composition, very unlike the monotony of the broad and deep sea floors. Rocks and soils, as well as mountains, valleys, and plains, differ greatly from place to place.

Mountain ranges are characteristic of the continents rather than of the sea floors, where plains of vast extent prevail. But mountain ranges occasionally rise from the sea bottom, showing their crests above the surface, as in the West Indies. Volcanoes and their lavas are among the few features possessed in common by the deep sea and the dry lands.

The continental shelves, overlapped by some of the oceans, have something of the variety of the lands from which they receive washings of gravel, sand, and clay.

While the deep-sea floor is always wet, dark, cold, and quiet, the land surface has many different kinds of weather and climate. Heavy rains are followed by clear sky; strong winds, by light winds or calms. A bare desert surface in the torrid zone may be heated at noon above 130°, and may cool nearly to freezing the next night. In

the frigid zone the frozen soil may warm and thaw at the surface during summer, but it will be frozen again, even to 80° below zero, the next winter.

Variations of temperature, so distinct on the land surface, rapidly decrease underground. At a depth of four or five feet daily changes are hardly perceptible; at a depth of twenty or thirty feet there is but little variation from the mean temperature of the year (about 80° in the torrid zone, near zero in far northern lands).

In northeastern Siberia, where the ground is frozen to a depth of 300 to 500 feet, grass and bushes grow when the soil thaws for a few feet in summer; but large trees are wanting. The mammoth, an ancient animal resembling a hairy elephant, but no longer found living, has on account of the extreme cold sometimes been preserved in the beds of sand and gravel that border some of the Siberian rivers, where it was buried at the time of river floods many centuries ago, and afterward frozen.

93. Activities of the Lands. — In nothing do the continents differ more strikingly from the deep-sea floors than in the activity of the various processes that go on upon the lands, and in the changes that the processes produce. The surface rocks split apart when water freezes in their crevices, or they slowly rust and decay under the action of air and water. A sheet of loosened rock waste is thus formed over most of the land surface. The various processes by which rock waste is produced are known under the general term *weathering*. Weathering varies greatly under different climates and with different rocks.

Every rock-ledge or quarry offers opportunity for observing the widespread process of weathering. The weathering of the older gravestones in cemeteries may frequently be noticed. In cities the different amounts of weathering on old and new stone buildings, or in buildings of different kinds of stone, serve to illustrate in a simple way the changes that occur on a much greater scale all over the lands.

FIG 59. A Quarry showing Weathered Rock

In the dry, mild, and equable climate of Egypt ancient statues have been but slightly weathered in several thousand years. A great stone monument, sixty feet high, known as Cleopatra's Needle, brought from Egypt to New York in 1880, was so much affected by the weather in a single winter that it became necessary to coat its surface with a preservative substance. In Egypt it had stood over 3000 years with little change.

In regions of plentiful rainfall and abundant vegetation weathering advances with comparative rapidity, and a deep soil is formed; solid rock may not be found for fifty or more feet below the surface. In high latitudes, where the temperature frequently rises and falls past the freezing point, frost is active in splitting rock masses into fragments.

94. The Wasting of the Lands.—Surface water, supplied by rain or melting snow, washes the finer rock waste down the slope of the land to the valley floors or to the streams, and the streams bear the waste along their channels, thus sweeping it from one place and spreading it over another, or washing it to the sea. Where streams run they rasp their channels with the rock grains that they bear along, and valleys are thus slowly worn in the surface of the land. The higher the land, the deeper the valleys may be cut.

The longer the period of wasting and washing, the more material is taken from the valley sides and the wider and more open the valleys become.

Large valleys, receiving many smaller branching valleys and ravines that dissect the surface of the land and lead streams from higher to lower ground, are among the most characteristic features of the continents. Valleys are the result of stream action and do not occur on the deep-sea floor. They are sometimes found beneath sea level, extending forward from the present coast line across the shallow continental shelf; they are then taken as proof of the lowering of that part of the continent.

The winds act with great effect on bare surfaces, sweeping finer rock waste into drifts (dunes), and raising the dust aloft to settle far away. The waves, currents, and tides of the ocean wear the edge of the land and the shallow continental margins, cutting cliffs and building sand reefs along the shores, and sweeping away the finer land waste.

The general process of wasting and washing, by which the land surface is slowly worn down and the deeper

structures of the earth's crust are attacked, is called denudation or erosion. The movement of land waste from one place to another by various agents (streams, currents, winds, waves, etc.) is called transportation. The process of laying down land waste on valley floors, in lake basins, and on sea floors is called deposition.

Illustrations of these various processes may be found on a small scale in the neighborhood of many schools. The wet-weather streams of roadsides and the waves in ponds or reservoirs exhibit in a small way the processes of erosion and transportation in large rivers and oceans. The strong action of winds on dusty roads and their lack of effect on the ground beneath grass or forests illustrate the contrast that prevails between wind action in dry and in moist regions.

The difference between the conditions that prevail on the land surface and on the sea floor is thus seen to be very great. The sea floor is enduringly quiet and silent. The tides of the deep sea are very faint. The creeping of cold polar water toward the equator must be almost imperceptible. The gain of the bottom by the steady shower of organic remains from the surface is very feeble, and the change of form by this gain must be exceedingly slow.

Although the changes caused in the form of the lands by weathering and washing are gradual, they have been so long continued that marvelous results have been produced. Not only are the lands deeply dissected where valleys have been worn in plateaus and mountains, but whole mountain ranges have been worn down to lowlands. The forms of

the land to-day can be appreciated only when it is seen that they are the present stage of a long series of changes. The description and explanation of land forms thus considered is the object of most of the remainder of this book.

The general wasting of a land surface is slow, but local changes are easily noted by the attentive observer. Sloping fields and roads are gullied by wet-weather streams. Much soil may be washed from a plowed hillside in a single rain storm. Landslides produce striking changes on mountain slopes and in the valleys below. Cataracts like Niagara wear back their cliffs more than a foot a year.

The land waste that is washed down a valley is deposited at the mouth of the stream in a lake or the sea, and thus the land is built out, forming a delta, which may grow forward perceptibly in a century. Ostia, once the port of ancient Rome, is now over a mile inland from the advancing front of the Tiber delta. Sea cliffs may be cut back by the waves; part of the exposed eastern bluff of Cape Cod, Massachusetts, is retreating at an average rate of three feet a year.

The rate of erosion on the lands varies greatly with rock structure, slope, and climate. The Mississippi carries enough land waste to lower its whole basin an inch in about three centuries. An inch in from one to ten centuries may be taken as a rough measure of erosion, averaged for large areas.

95. Useful Products of the Lands. — The rock of the earth's crust in the lands is of great service in building and

road making; hence it is often quarried. Clay is burned to make bricks, used in building and street paving. Limestone when heated ("burned") is changed to lime, used in making mortar. Coal, found in layers between strata of clays and sandstones, is the most useful kind of fuel. Rock oil, or petroleum, is of great value as a fuel for lamps, and in many other ways. The ores of many metals are mined and smelted, to supply man's needs; iron, copper, lead, tin, and zinc are the most useful metals in manufactures; gold and silver are used as money and in the arts. Precious stones or gems, such as the diamond, ruby, and emerald, are highly prized for their beauty and rarity.

All these products of the lands play an important part in the advance of civilization. Spain has iron ore but no coal. England has abundant coal and iron ore. How is the present condition of these two countries affected by the presence and absence of coal supply? The United States possesses extensive coal fields and abundant deposits of iron ore, as well as other mineral products in great variety. Argentina possesses relatively little mineral wealth. What comparison can you make between these two countries in other respects?

QUESTIONS

SECS. 88, 89, 90. What is the area of the globe? of the lands? State three remarkable facts concerning the distribution of the lands. Why are the terms Old World and New World not appropriate in physical geography? State the relation of the larger islands to the continents. Compare land heights and ocean depths. State the proportion of high land to deep ocean.

91. What changes are taking place in continental outline? Give some examples.

92. Contrast the land surface and the sea floor as to form; as to changes of temperature. Contrast the distribution of mountain chains and of volcanoes. How does temperature vary underground? Describe the effects of extreme cold in northeastern Siberia.

93. What changes take place on the lands? What is weathering? Give examples of it. Name some of its effects. How does frost act and where is it most effective?

94. Describe the action of streams. How are the depth and width of valleys determined? Why are valleys characteristic of the lands? How are the lands affected by the winds? by waves and tides? Define denudation. What effects of erosion have you seen? State the effects of long-continued erosion. What changes have occurred on shore lines? Upon what does the rate of erosion depend? What is its average rate?

95. What are some of the useful products of the earth's crust? What comparison can you make between England and Spain? between the United States and Argentina?

CHAPTER V

PLAINS AND PLATEAUS

96. Introductory Example. — In certain parts of the world the hills bordering a mountain range descend directly to the seashore. Rock waste is washed from the mountain slopes and carried down the valleys by streams. The larger rivers build deltas at their mouths, and here the sea is bordered by low land. Waves beat on the coast and cut cliffs in the headlands between the valleys; here the sea is bordered by high land. The waste of the land is spread over the neighboring sea floor by waves and currents.

Figure 60 is a picture of a model representing a region of this kind. Mountains and ridges of varied form descend toward the shore line. A river in a large central valley receives the streams with their rock waste from a number of branching valleys and has built a delta at its mouth. This means that while the land has been eroded and roughened by the action of weather and streams the sea floor has been smoothed by the gain of land waste. The depth and number of the valleys show that already much waste has been carried into the neighboring sea. The dredge brings up gravel, sand, and mud from the sea bottom, the sediments usually being of finer grain as distance from land and depth of water increase.

Figure 61 is a map of part of the mountains shown in Figure 60. The form of the ridges is here indicated by short lines, called hachure

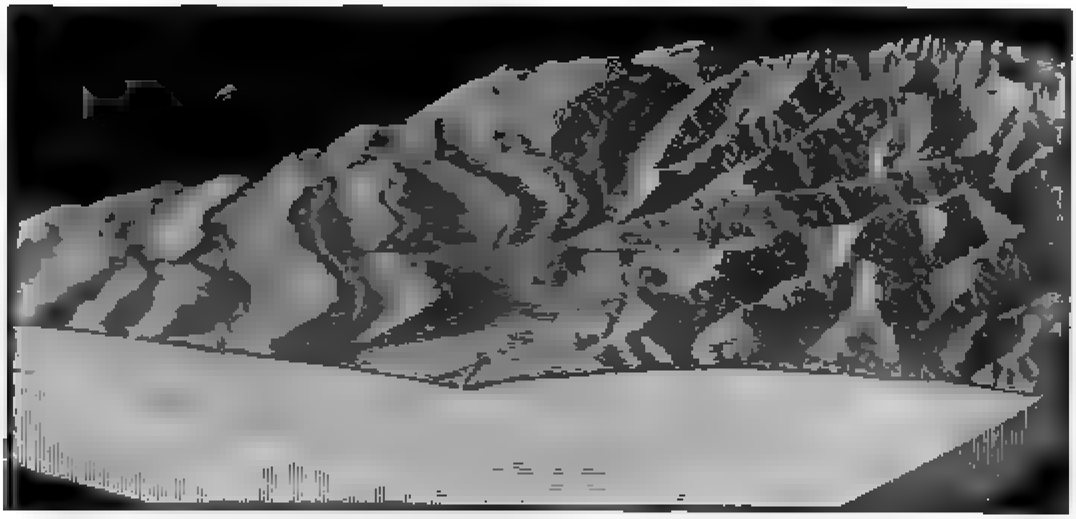

FIG. 60. Mountains bordering the Sea

lines, which show the direction in which the slopes descend. Gentle slopes may be represented by long fine lines, steep slopes by short heavier lines. This map may serve as a sample for a number of others that should be drawn from the figures on later pages.

FIG. 61. Sample Map of a Mountainous Coast

A rugged land like that of Figure 60 seldom supports a large population, for it is not easy to gain a living on steep mountain sides. It is only in the valleys that strips of flat land, suitable for easy occupation, can be found. Most of the population in such a region is gathered

in villages near the mouths of the large rivers, where the valleys are wider and the ridges between them are lower. Roads cannot easily follow the shore, for many of the cliffs are washed to their base at every high tide. In passing from one valley village to another the traveler must climb over a ridge; this is hard work and it discourages settlement. Many dwellers in the shore villages are seafarers and fishermen, although there are few protected harbors, for the shore line is comparatively straight.

The coast of California presents many stretches of this kind. The Sierra Santa Lucia, south of Monterey, descends boldly to the sea, its spurs being cut off in great cliffs. The shore is harborless and thinly inhabited for a distance of seventy miles.

97. Narrow Coastal Plains. — There are some regions where the foothills of the mountains descend to a lowland, and the lowland slopes gently forward to the sea. Such a lowland is called a coastal plain. The gentle slope of the lowland is continued in the slowly deepening sea floor. The form of the land is here much more favorable to human occupation than in the previous example.

Plains of this kind are often divided into many similar strips by the shallow valleys of streams that flow across them from the mountains. Each strip of the plain is so smooth and so nearly level that a great part of the rainfall enters the open soil, instead of running off in streams. The plain is built of layers or strata of gravel, sand, and clay, the uppermost layer or stratum forming the surface of the plain. The pebbles of the gravel often

resemble the harder rocks of the hilly background; the clay often contains shells like those living in the sea. Figure 62 shows a region of this kind.

Trace the line between the mountains and the coastal plain in Figure 62. How many streams are seen crossing the plain? Which stream has the broadest valley? Why? Compare the depth of the valleys in the plain with that of the valleys in the mountains.

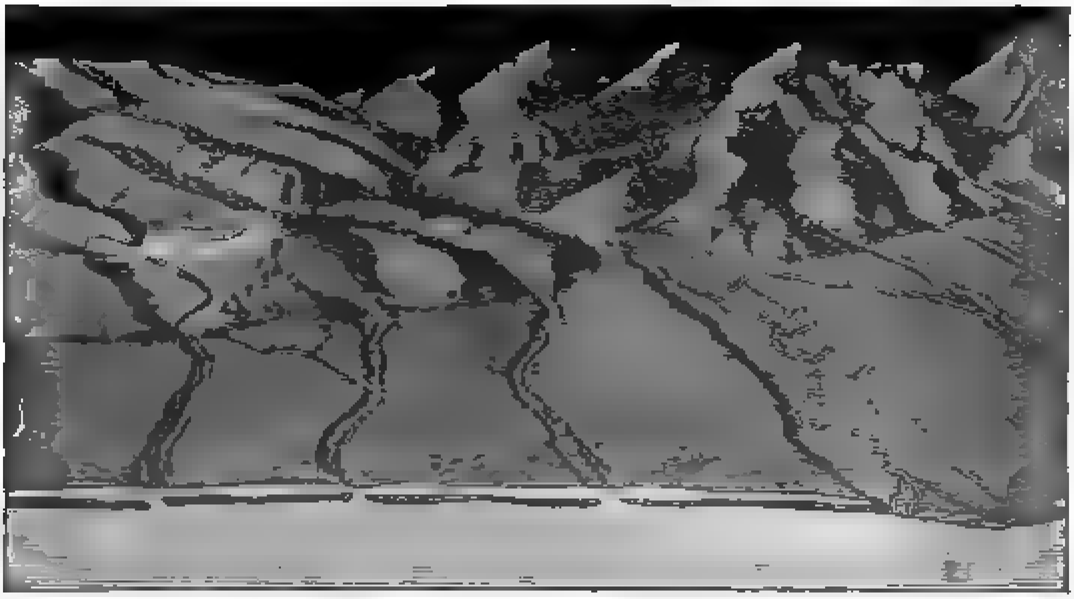

FIG 62 Narrow Coastal Plain

Draw a map to represent part of the coastal plain of Figure 62 and some of the hills bordering its inner margin. Notice that in the figure the streams crossing the plain are foreshortened, while the spaces between the streams are on true scale. Figure 63 illustrates the way in which the map should be drawn.

Little ravines have been eroded by wet-weather streams in the side slopes of the plain bordering the valleys. Even the larger valleys have been slowly eroded by the rivers that flow through them. In the future the plain will be

more carved or dissected; in the past it was less dissected. Before any valleys were cut the different parts of the plain were all united in a continuous, even surface.

In view of all this, it must be concluded that the coastal plain in Figure 62 was once part of a shallow sea bottom and that this region was then like the sea-skirted mountains of Figure 60. Since then the relative level of the land and sea must have been altered, laying bare a part of the smoothed sea bottom to form the coastal plain.

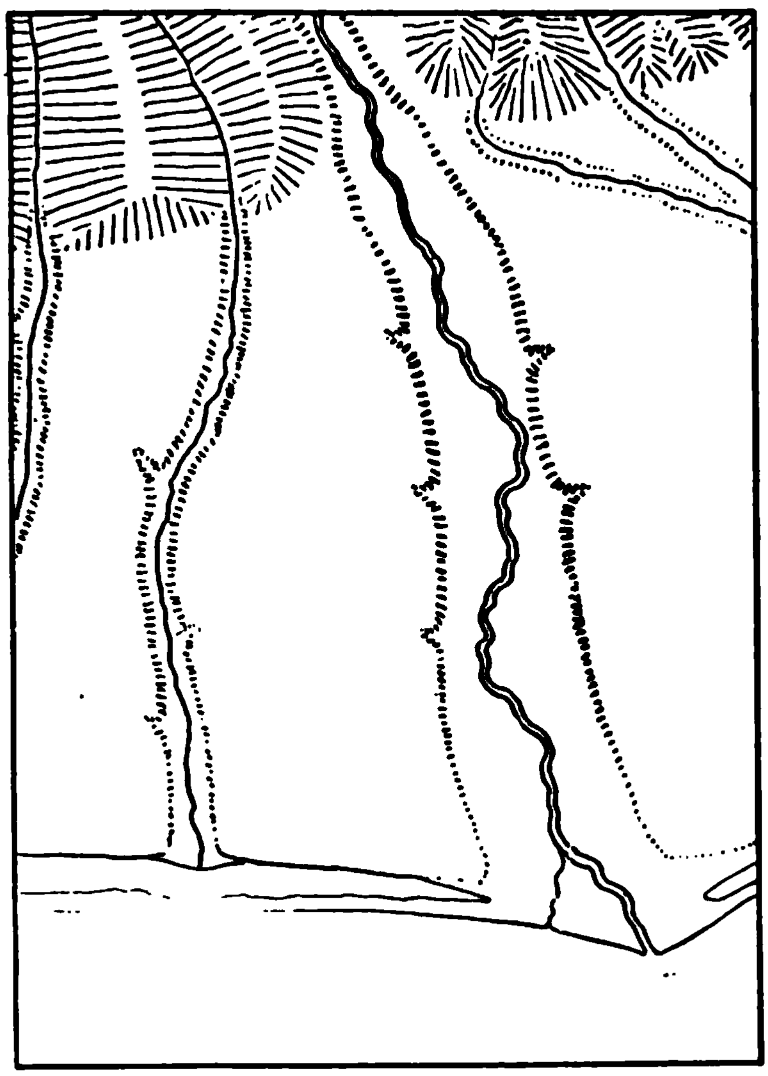
FIG. 63. Sample Map of a Narrow Coastal Plain

As the region now stands higher than before, the rivers tend to wear down their valleys to the new level of the sea at their mouths; the valley sides waste away, and thus the valleys slowly become wider; but the streams cannot wear the valleys deeper than the surface of the sea at their mouths. The level of the sea is therefore called the *baselevel* of the region.

Slender belts of a very narrow coastal plain, less than a mile wide, are found along parts of the western coast of Scotland; they are even narrower than the plain represented in Figure 62, being wide enough for only a single row of

fields. The houses of the farmers are generally placed near the inner margin of the plain; a few fields are cleared on the lower slopes of the back country; cattle pasture on the higher hillsides; the cultivated crops are gathered chiefly from the smooth surface of the little plain.

FIG. 64. A Narrow Coastal Plain in Scotland

A number of narrow and low coastal plains occur along the coast of Oregon. They are one or two miles wide and twenty or more miles long. Heavily forested mountains rise in the background, too uneven for easy occupation; but the even surface and gentle slope of the coastal plains make them attractive to settlement, although they suffer the disadvantage of having no good harbors.

The eastern coast of Mexico in the neighborhood of Vera Cruz is bordered by a low coastal plain about fifty miles

wide, back of which the mountains rise rather abruptly. The plain is called the *tierra caliente*, or hot country. It is sandy, malarial, and relatively infertile. Vera Cruz, the chief port for the interior highlands, has a poorly protected anchorage on the open shore.

96. Broad Coastal Plains. — Figure 65 represents a broader coastal plain than the preceding examples. The

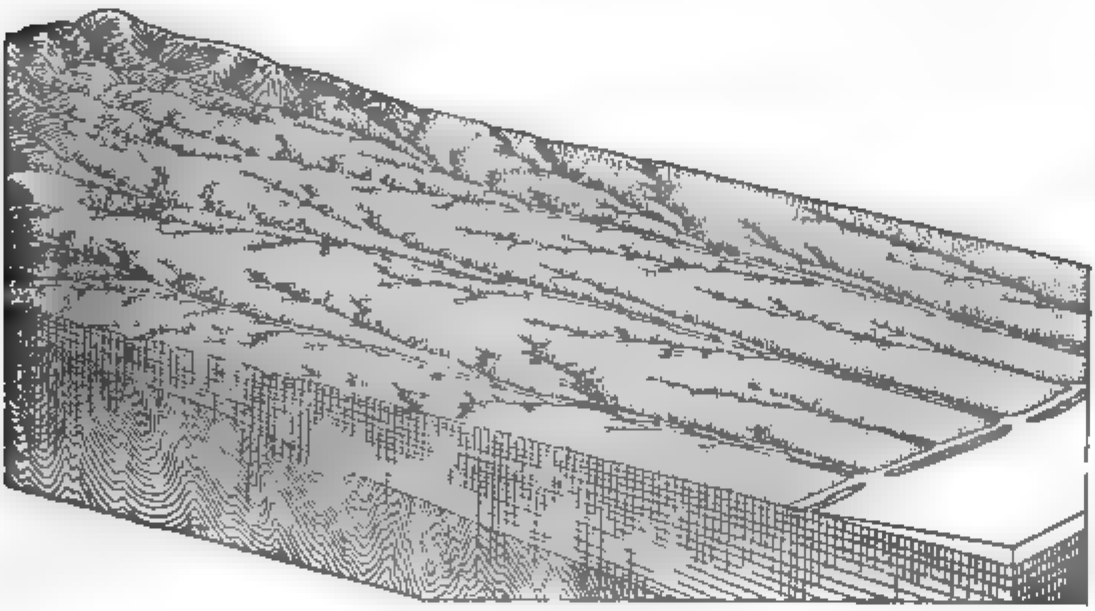

FIG. 65. Broad Coastal Plain

outer part of this plain is much like the plain in Figure 62; but the inner part is more cut by branching valleys and ravines, so that it presents a hilly rather than a plain surface, and the larger rivers have broader valleys than before. The unevenness, or "relief," of the surface increases inward from the shore line in consequence of the greater depth to which the valleys are cut in the higher part of the plain. Where the uplands are much interrupted by branching valleys the plain is said to be well dissected.

During the slow uplift of the region different kinds of sediments may have been laid down near the shore, as the sea retired from the plain. Hence the soils of such plains are commonly of different kinds in the inner, middle, and outer parts, being arranged in belts roughly parallel to the length of the plain.

The Atlantic coastal plain of the Southern States, of which a characteristic portion is included in South Carolina, Figure 66, is dissected by many branching valleys in its inner part. It may be divided into several belts parallel to the shore line. The outer or coastal lowland is a smooth plain, with open pine woods or grassy savannahs; this division is about fifty miles wide, rising so gently that it seems level to the eye. Its surface is very poorly drained.

FIG. 66. Coastal Plain of the Carolinas

The plain slowly rises inland with gently rolling surface; here the soil is better than in the first belt, and much cotton is raised. Farther inland still the surface becomes more sandy again and more hilly, giving extensive views seaward across the lower plain. A hundred miles inland

a belt of hilly uplands stands 600 or 700 feet above the sea, covered with pine forests. Here the plain is well dissected, its original surface being almost entirely destroyed by the action of many streams in carving their valleys and by the action of the weather in opening the valley slopes.

Then come the hills of the older land (the Piedmont belt, here not mountainous, but of moderate relief), whence

FIG. 67. A Truck Farm on the North Carolina Coastal Plain

the strata of the plain have received their sediments, and where the rivers are now cutting down narrow valleys beneath their former valley floors.

The soil belts on this plain exert an important control over the industries of the people. The less sandy soils are occupied by cotton plantations. Extensive pine forests on the more sandy belts furnish much lumber, tar, and turpentine.

The moist swampy soils near the coast are well adapted to the cultivation of rice. The more limy layers of the plain are dug up to fertilize the more sandy fields, and the richest of these limy deposits are exported to other states to be used as fertilizers. In North Carolina numerous farms on the coastal plain furnish vegetables for the markets of northern cities.

99. Belted Coastal Plains.—Figure 68 exhibits a coastal plain which may be divided into three belts parallel to the

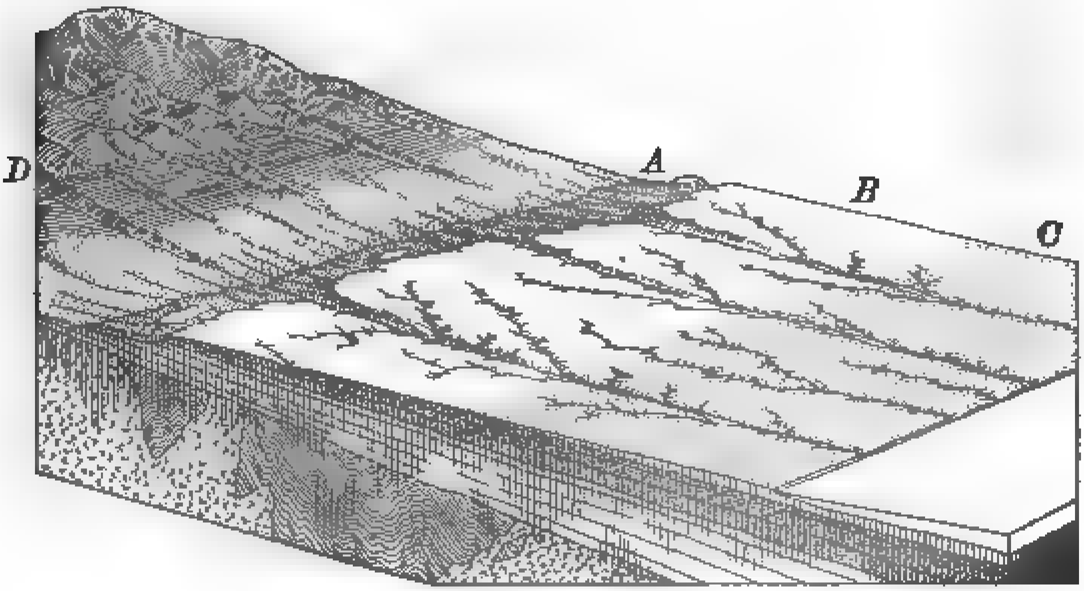

FIG. 68. A Belted Coastal Plain

shore line, each one ten, twenty, or more miles wide; the innermost (*A*) is a lowland; the middle belt (*B*) is an upland of stronger rock layers, several hundred feet above the lowland; the outer belt (*C*) is a smooth coastal lowland. The several belts recall the beltlike arrangement of soils described in the case of a broad coastal plain, but here the middle belt forms an upland that runs about

parallel to the shore line and stands between an inner and an outer lowland. The upland descends by a rather steep slope to the inner lowland, and by a long, gentle, outlooking slope to the coastal lowland.[1]

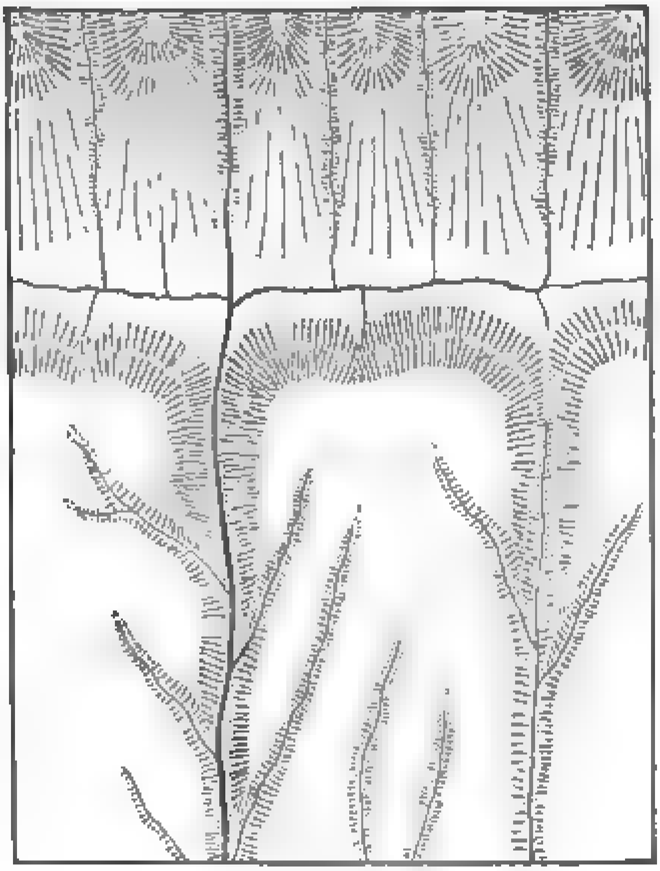

FIG. 69. Sample Map of Part of a Belted Coastal Plain

In Figure 68 the front of the diagram is drawn to represent what would be seen on the side of a very deep cut that might be imagined to cross the plain. The layers of clays, sandstones, and other strata that form the plain are thus shown, gently slanting under the sea. Where is the uppermost layer of the series, that is, the layer that was last deposited? What part of the belted plain does it cover? Where are the under layers (the first deposited)? Where do they reach the present surface of the belted plain? Which layers reach the surface of the upland part of the belted plain?

Draw an outline map of the district shown in Figure 68. A sample of part of it is shown in Figure 69. Note that some small streams must run inland, down the inner slope of the upland.

[1] An upland of this kind may be called a *cuesta*, following a word of Spanish origin used in New Mexico for low ridges of steep descent on one side and gentle slope on the other.

Compare the arrangement of the rivers and streams with those shown in the map, Figure 63, drawn from Figure 62.

The reason for the arrangement of upland and lowland may now be understood. The under layers of this coastal plain are weaker than the middle layers; hence the under layers, which reach the surface of the plain near its inner border, are already worn down to a lowland, while the more resistant middle layers still preserve an upland height.

Trace the river first seen at *D*, Figure 68, and describe the several belts of country that it crosses on the way to the sea. Where is its valley deep? where shallow?

A good example of this kind of coastal plain is found in southern New Jersey, Figure 70. The Delaware river below Trenton runs along the inner lowland. Here is a belt of pottery clays, of which much crockery and earthenware are made. Then comes a belt of farming country on rolling hilly ground, which contains layers of marl (limy clay); the marl is dug to serve as a fertilizer on less productive soils. The hills rise to an upland that descends in a long gentle slope southeastward to a lowland plain by the sea; its soil is sandy and its even surface is generally overgrown with pine forests. Short arms of the sea enter the lower valleys, giving harborage for small vessels; many fishermen live in the shore villages. A belt of shallow salt-water lagoons with extensive marshes of reeds borders the mainland for a breadth of about five miles. Finally come the sand reefs, half a mile or more wide, inclosing the lagoons. The reefs are interrupted by inlets, connecting the lagoons with the sea.

Name the direction of the Delaware and the Schuylkill as they flow into the inner lowland; of the Delaware in the inner lowland; of the streams that flow down the inner slope of the cuesta and

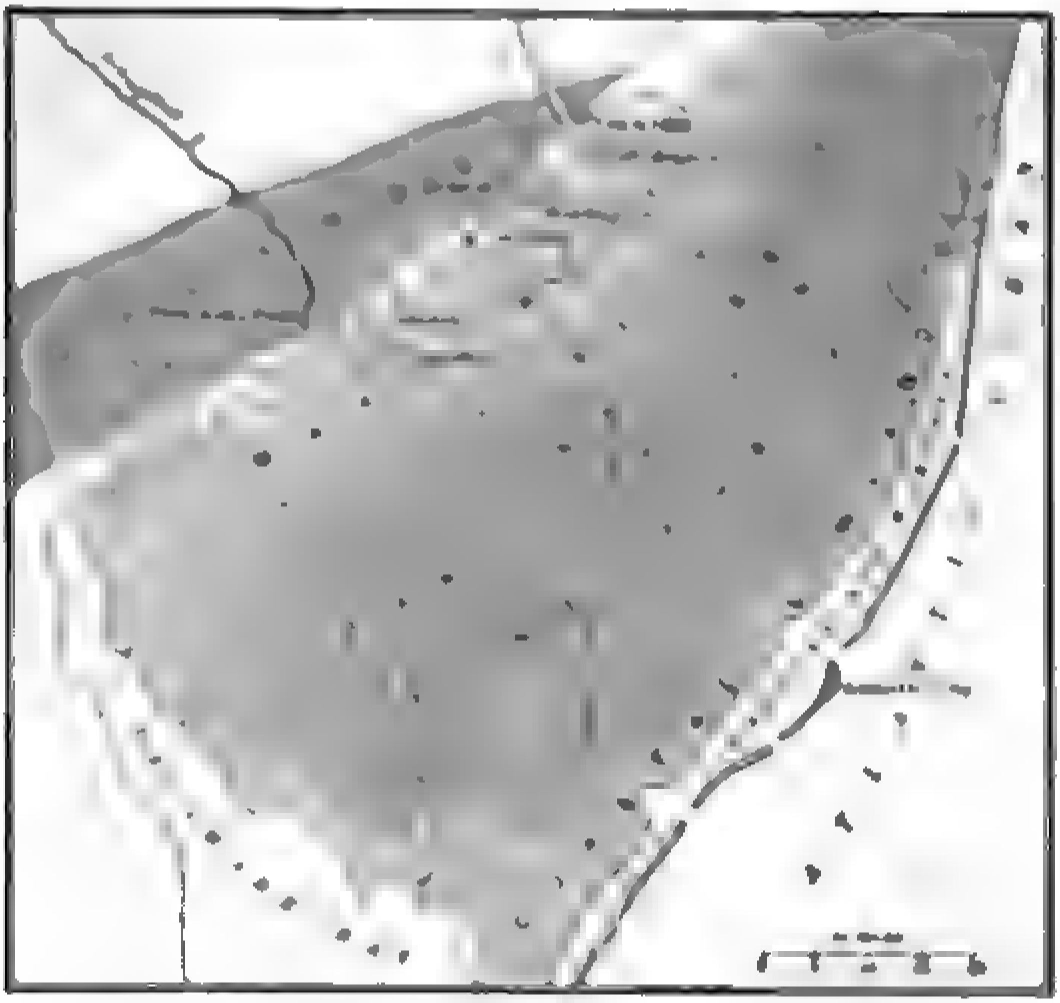

FIG. 70. The Belted Coastal Plain of Southern New Jersey.

across the marl belt; of the streams on the outer slope of the cuesta. Which is the steeper slope of the cuesta? How is this known? Compare the arrangement of all these streams with those shown in Figure [illegible].

What is the average breadth of the clay belt? of the marl belt? of the hilly belt? of the sandy plains? of the coastal lowland? How far is it from Philadelphia to Atlantic City?

100. Embayed Coastal Plains. — The region here figured does not at first sight seem to belong to the family of coastal plains. Long shallow arms of the sea enter between low hilly arms of the land. Rivers from the back country enter the heads of the long bays; small streams from every little valley between the hills of the

FIG. 71. An Embayed Coastal Plain

land arms enter little bays or coves on the sides of the larger bays.

This diagram represents a coastal plain which has been depressed, so that its valley floors are "drowned" beneath the sea. Before drowning, the region must have stood for a long time higher above baselevel than now, for the valleys evidently had been eroded and widely opened before the depression of the region occurred. Many side valleys had been formed, so that the uplands between the larger rivers had been dissected into branching spurs. Now the outer coastal lowland and the broad valley floors are under

water, the latter being occupied by the bays that enter far toward the oldland, while the groups of hills stand forth as ragged arms of the land. The former simple shore line is thus exchanged for a very irregular shore line.

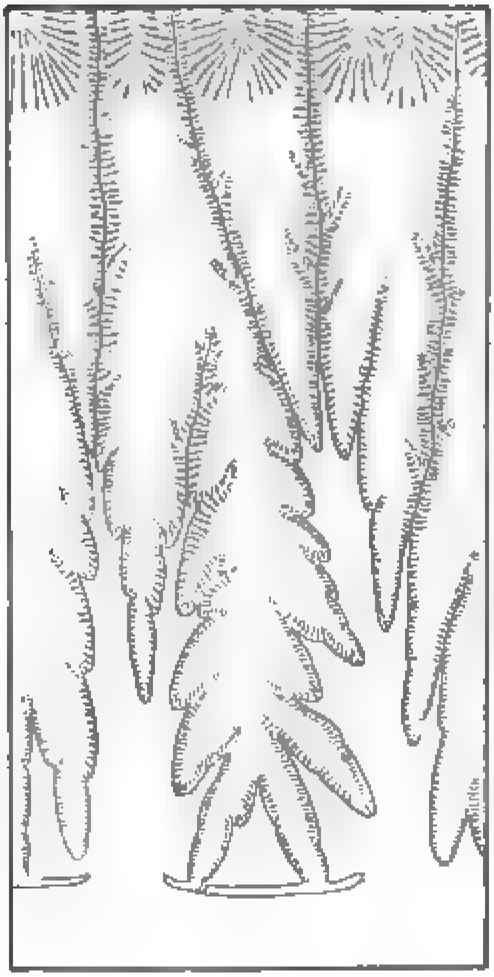
Fig. 72. Sample Map of an Embayed Coastal Plain

Draw a map of part of the embayed coastal plain shown in Figure 71, after the style of the outline in Figure 72. Compare Figures 65 and 71. Point out the inner border of the coastal plain in each one. In what respects do the two figures agree? In what do they differ? How has the difference been produced? In each one trace a river from the oldland to its mouth. What difference is noted?

The relative change in the attitude of land and sea is here opposite to that inferred in the previous examples. Since the depression of the region the land heads have been more or less cut back by the waves, and the bay heads have been somewhat filled by marshy deltas. But the drowning cannot have taken place long ago, as the earth counts time, for the changes in the land heads and bay heads are of moderate amount.

The Atlantic coastal plain from Delaware bay to Pamlico sound presents many examples that fall under this class.

The outer shore line is for the most part a sand reef, inclosing lagoons. Many branching bays extend inland, the largest being Chesapeake bay. Navigable arms of the sea thus alternate with dissected arms of the land.

Partly drowned coastal plains exert a peculiar control over the distribution and occupation of their population. The greater part of the valley lowlands is lost, and the people must make the most of the hilly land arms that remain above sea level. The axis of each of the larger arms is generally followed by a main road, making its way from village to village among the upland farms and giving forth side roads to villages on the smaller land arms or at the little bay heads. Indicate the place of such roads and villages on Figures 71 and 72.

The shallow bays are valuable for fishing grounds. More important centers of population are found either near the heads of the larger bays, where the large rivers come out from the back country and reach tide water, or near the mouths of the bays where the outer sand reefs are not continuous and the ocean is easily reached. Baltimore and Norfolk are good examples of cities thus situated. The outer shore line is inhospitable; its long sand reefs offer no good landing place, and the narrow tidal inlets allow entrance only to small-sized vessels. Where would such a view as that of Figure 73 be found in Figure 71?

In the early history of "tide-water Virginia" the numerous drowned valleys afforded easier communication between the settlements than was found overland through the forests of the coastal plain.

101. The Fall Line. — A large river whose valley is extended across a coastal plain often has low falls or rapids near the inner margin of the plain, which determine the "head of navigation," or uppermost point that can be reached by vessels from the river mouth. A line drawn through the falls on successive rivers is called the fall line.

FIG. 73. A Branch of Chesapeake Bay, Maryland

The falls occur where the river passes from a steeper slope on the resistant rocks of the older land to a nearly level channel excavated in the weak strata of the plain.

On coastal plains of a considerable breadth settlements near the mouth and at the head of navigation of the larger rivers often develop into important cities. The lower city is the seaport of the region. The upper city bears closer relation to local industries and traffic; it lies in the midst of a diversified region, with strong water power for manufacturing the varied products of rock and soil. In South Carolina, Columbia lies on the Congaree river,

where it passes from the older land to the dissected plain. Charleston lies at the outer edge of the coastal lowland on the widened course of a small river where the tide comes in from the sea.

The fall line along the inner margin of the Atlantic coastal plain of the United States is marked by important cities on nearly every large river that crosses it. Trenton, Philadelphia (at the falls of the Schuylkill), Richmond, Raleigh, Camden, Columbia, and Augusta are all thus located.

The origin of the forces sufficient to deform the crust of the earth and to elevate or depress a coastal plain is not well understood. It is necessary that the student of physical geography should recognize that elevation and depression have actually taken place, and should understand the importance of such movements in controlling the forms of the lands and the conditions of their inhabitants; but the processes that cause such movements must be left to the more advanced study of geology.

Coastal plains, narrow or broad, belted or embayed, occur along parts of the border of different continents. They resemble more or less closely the examples here given. The coastal slope of Guiana and the plains of Patagonia, South America, belong in this group of forms.

102. Inland Plains. — The Great plains of the central United States slope gently forward from the Rocky mountains. They are formed of many layers of sands, clays, and gravels, washed from the mountains and now lying one over the other, many hundred feet in total thickness and nearly horizontal. Some of the layers were deposited

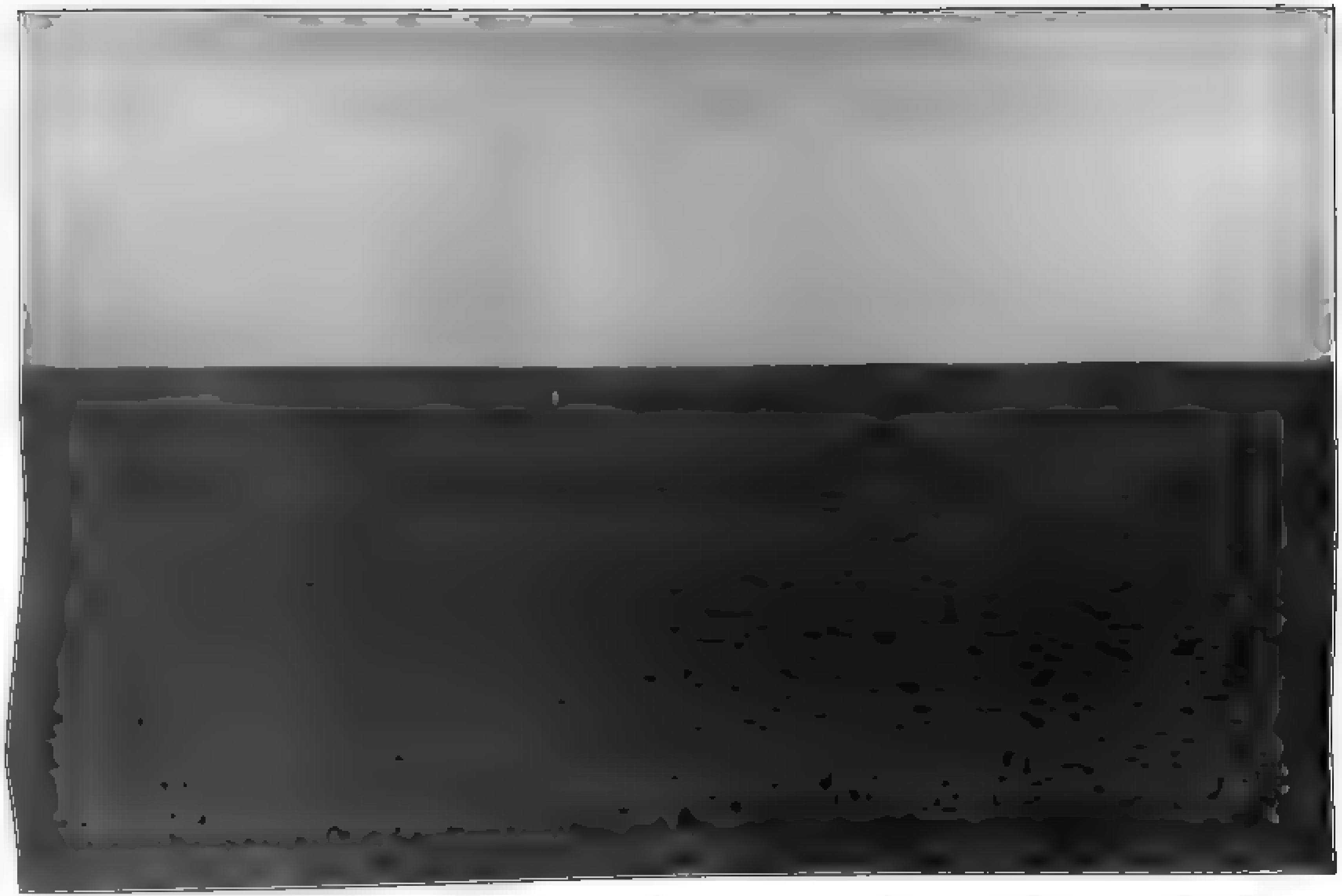

Plate VI. The Great Plains

when the region was below sea level; some were spread over the uplifted sea bottom by rivers when the region was too low to be dissected.

The plains are now high enough to be more or less dissected by streams and rivers whose valleys vary in depth and width; but the upland spaces between the valleys often preserve a comparatively even surface over large distances. In some districts, vast areas stretching farther than the eye can reach are monotonously even and almost as uniform in soil as in surface. In other districts, valleys are deeper and closer together, and the spaces between them are made hilly by the branching ravines of side streams.

Within the United States the Great plains are treeless for 500 miles east of the Rocky mountains, except on certain hills and bluffs which occasionally rise above the general level, or in the valleys which sink below it. The absence of trees is due to the dryness of the climate, and this in turn is due to the general course of the westerly winds whose moisture has been left on the mountain ranges between the plains and the Pacific. Agriculture is impossible in the drier southern parts without irrigation. Farther north in Canada the climate is moister, and the plains are forested. In still higher latitudes the surface is treeless; the warmth of summer melts only the upper part of the soil, and vegetation is low and stunted.

The treeless plains possess little mineral wealth, and they have no forests to supply lumber; hence they cannot become a closely populated manufacturing region; but they

have a more or less abundant growth of herbage, which once supported herds of countless buffaloes. Now that the buffaloes have been killed off, their place is taken by cattle which range over the plains, wandering back and forth over the uplands between the valleys that they visit for water. A number of railroads traverse the plains and carry, among other things, many cattle to eastern markets.

The plains of western Siberia resemble the Great plains of the central United States. They slope gently away from the mountains of central Asia. They have a moderate altitude above sea level and preserve a generally even surface over hundreds of miles. Marshes and shallow lakes lie in faint depressions, as if the hollows in the original surface of the plains had not yet been drained by river action. The narrow valleys are few and far between; they can never be cut deep while the region stands low, and they have not yet been worn wide.

The more northern part of these plains is treeless because the ground is frozen. The central part is forested; but south of latitude 50° to 55° the plains have a light rainfall and are again treeless; clothed with thin grass in summer; cold, barren, and wind swept in winter.

The treeless plains have long been the home of wandering tribes, whose wealth is not in fixed possessions, but in herds and flocks driven from place to place for pasture. The people live in tents and move about without definite limits to their lands. On account of their wandering habits they are called *nomads* (wanderers). Every man is necessarily a horseman, skilled in nearly all the arts of a wandering life.

103. Belted Inland Plains. — In Wisconsin, far inland from the ocean, the northern part of the state is occupied by rugged highlands of resistant rocks. Adjoining on the south and east are plains and uplands arranged in belts, their rock layers sloping gently away from the highlands and lapping one over another like great shingles.

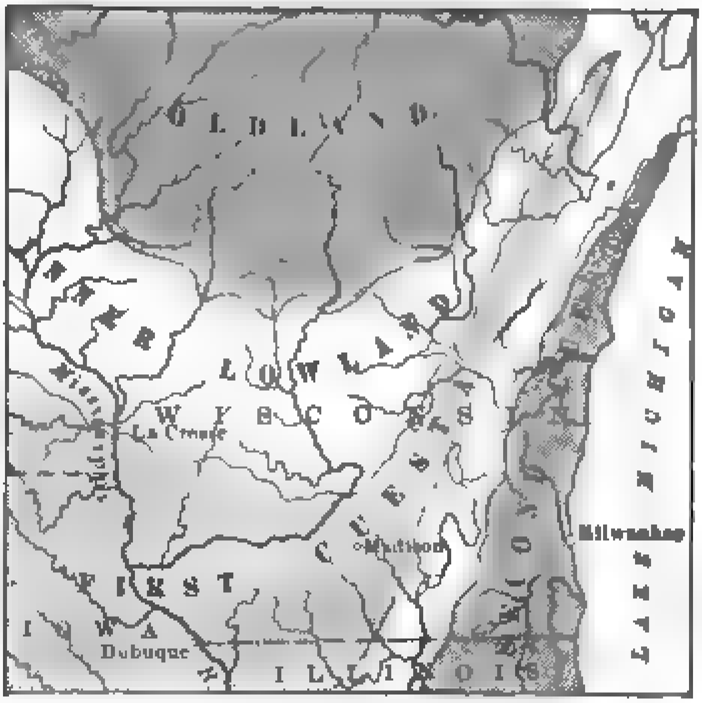

FIG. 74. Ancient Coastal Plain of Wisconsin

Fragments of the highland rocks are found in the lower members of the overlapping strata; numerous marine fossils, like corals and shellfish, occur in many layers. All the layers are well consolidated; the firmer ones form belts of hilly uplands, between which the weaker layers are worn down to lower plains.

Although the sea may now be a thousand miles away, the belts of upland and plain are easily seen to be similar to the belted coastal plains already described, while the rugged highlands are the older land from which the strata of the plains and uplands were long ago derived.

This is an ancient coastal plain; that is, a region that began its existence as a coastal plain ages ago in the earth's history, and that now stands in the interior of the

continent because successive uplifts have broadened the continental surface.

Belted inland plains, similar to the example in Wisconsin, occur in many parts of the world, usually presenting a succession of hilly uplands and intermediate plains similar to those here described. Good examples are found in south-central England and in northeastern France. They all enjoy the advantage that comes from diversity of form and products and from the resulting variety of occupations that they support.

104. Plateaus. — When plains stand at a considerable height above the sea level they are called plateaus. No definite limit of height can be given to separate the two classes of forms. In elevated regions the lower parts may be called plains, even though they are more than 2000 or 3000 feet above sea level; in low regions the higher parts may be called plateaus, even though not higher than 1000 or 2000 feet.

Plateaus are sometimes traversed by deep and narrow valleys or canyons, branching in various directions. The canyons are cut down to a great depth by their streams because the plateau surface stands high above baselevel.

Plateaus are generally built of horizontal rock layers of various kinds, whose edges are well shown in the canyon walls. In Figures 75, 76, and 77 a deep cut is imagined across the front of the view, so as to show more clearly the rock layers that crop out in the canyon walls. The broad uplands between the canyons have a comparatively even surface across which it is easy to travel, but the deep canyons are almost impassable.

The walls of the narrower canyons consist of a succession of cliffs and slopes, often too steep to be climbed. The cliffs are formed on the hard resistant layers, which are strong enough to stand with a steep face; the slopes are formed on the weak layers, which are more easily weathered back to a slant.

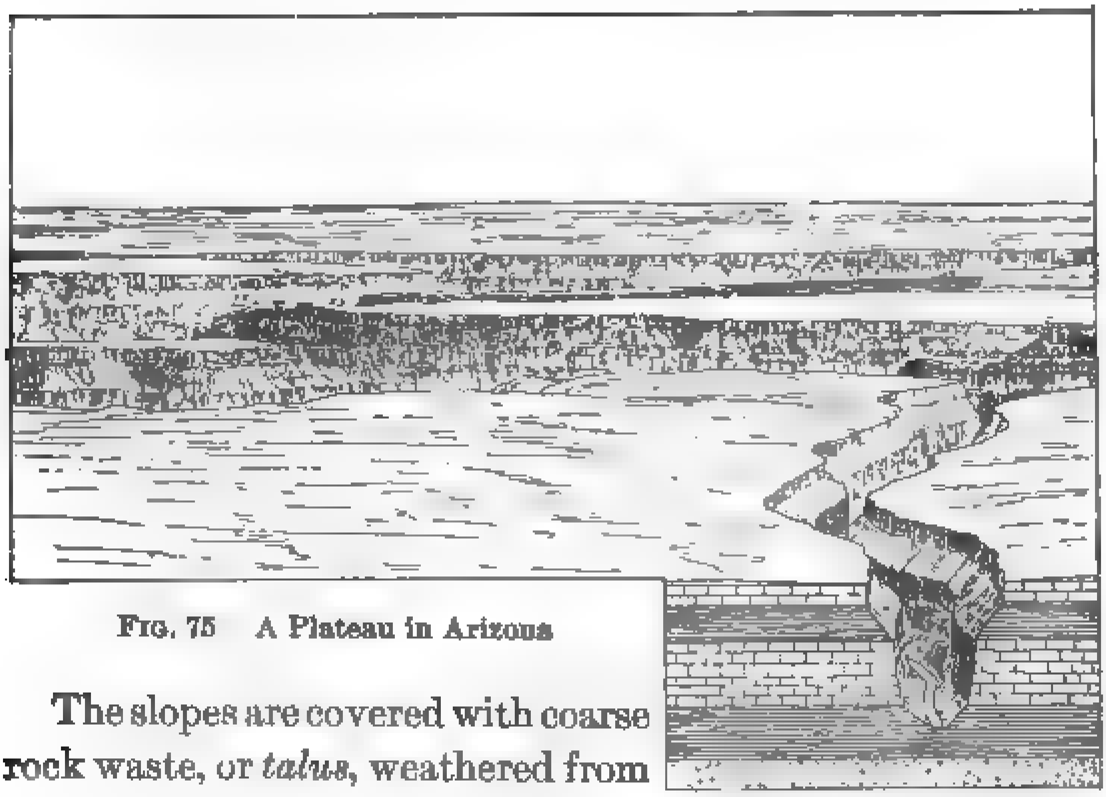

FIG. 75 A Plateau in Arizona

The slopes are covered with coarse rock waste, or *talus*, weathered from the cliffs above. The rock waste weathers and falls from each cliff, and rolls, washes, and creeps down each slope to the top of the cliff next below, where it falls again, shattering to fragments; at last it reaches the stream, where its finer parts are rapidly washed away. Thus the cliffs and slopes wear back or retreat, and the canyon widens.

As a canyon widens, a platform or bench is formed on the top of the stronger cliffs; it is then often possible to descend into the canyon by climbing down crevices in the cliffs, from platform to platform.

Point out the cliffs, slopes, and platforms of the canyon walls in Figures 76 and 77. Where are the highest cliffs, the longest slopes, the broadest platforms? Which layers, shown in the front of the diagram, are resistant? Which are weak?

The slow creeping of waste down the slopes of the valley sides is caused by very slight movements of the fragments and particles as they warm by day and cool by night, as

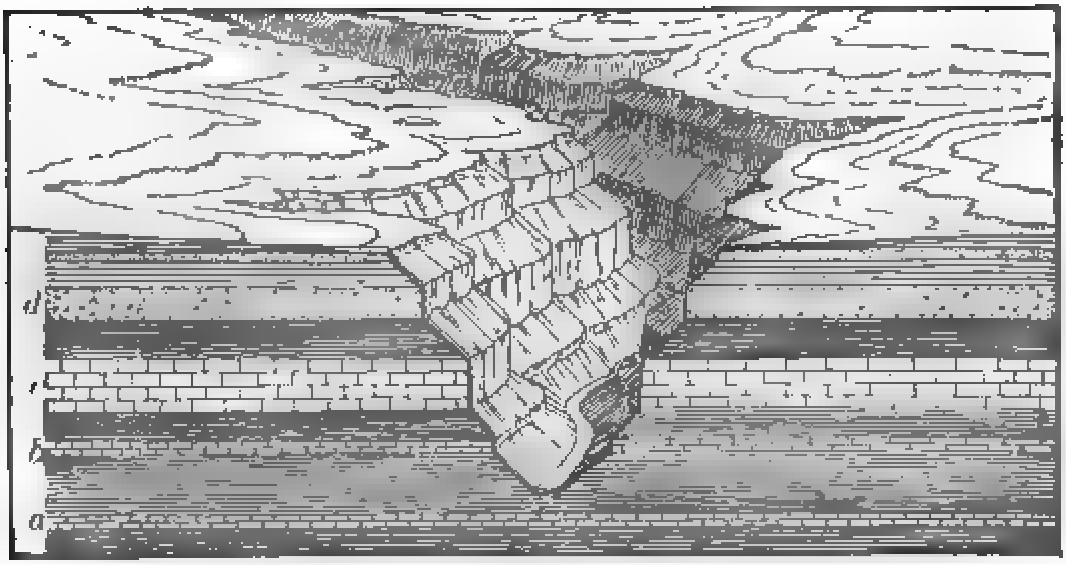

Fig. 76. Diagram of a Narrow Canyon

they are wet by rain and dried in fair weather, or as they are moved by the freezing and thawing of films of water between them. The movement is more noticeable on steep slopes, but it does not cease even on the gentler slopes.

The slow downhill creeping of weathered fragments, aided by the surface washing of fine particles in wet weather, is the chief means of moving waste down from the high ground to the streams in the valley bottoms.

As the canyon is eroded by the main river, ravines are cut in the canyon walls by streams that rise on the plateau.

The deeper the main canyon is eroded, the deeper the side ravines are worn down, and the more the plateau is dissected. Yet in the stage shown in Figure 77 the great work of wearing away the plateau is only well begun.

The lofty plateaus of northern Arizona are traversed from east to west by the Grand canyon of the Colorado, from 4000 to 5000 feet deep. The dry climate of the plateau

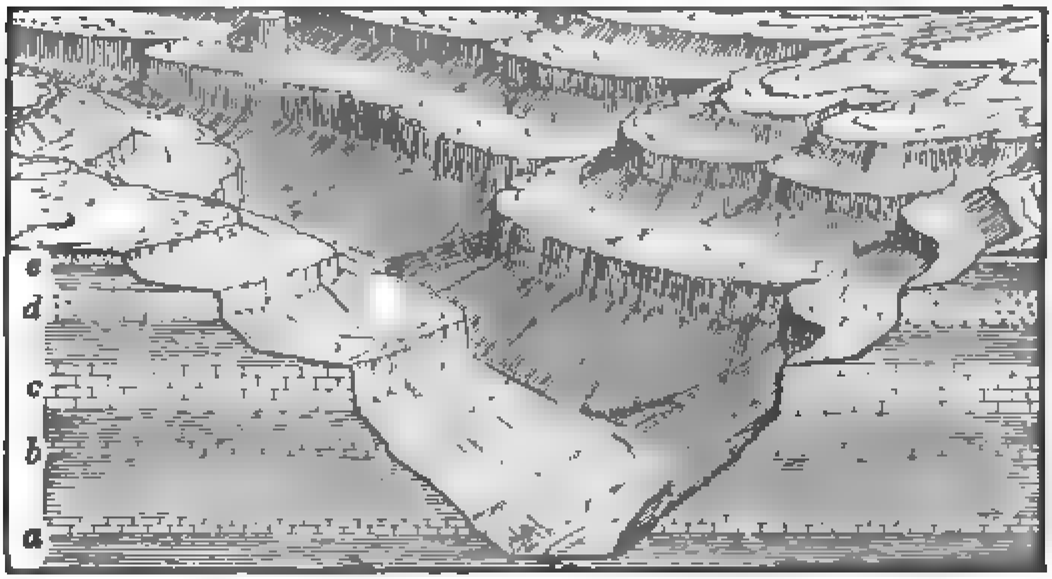

FIG. 77. Diagram of a Widened Canyon

makes vegetation scanty. The region offers no temptation to settlement, however marvelous it is to the explorer. Much of it is desolate, occupied by a few Indians, who subsist by "cultivating little patches of corn, gathering seeds, eating the fruits and fleshy stalks of cactus plants, and catching a rabbit or lizard now and then; dirty, squalid, but happy, and boasting of their rocky land as the very Eden of the earth."

The great elevation of this plateau permits an unusual depth of canyon cutting. The massive strong and weak

strata of which the plateau is built produce strong cliffs and long talus slopes on the canyon walls. Far down in the bottom of the great trench runs the tawny Colorado, turbid with waste that is showered from the walls in rocky avalanches or swept in from side canyons by cloud-burst torrents. The water, bearing abundant waste, is still rasping down the rocks in its falls and rapids. Deep as the canyon is, it has been cut down only by the river. There is no indication of clefts or fractures along the river course.

Unlike most great rivers whose valleys serve as paths of travel, the Colorado is almost inaccessible along its canyon. Only one exploring party has successfully gone down the canyon, and their narrative is a wonderful history of scientific adventure. When their boats once entered the canyon, retreat was impossible against the swift current. Escape by climbing the walls was hazardous. To descend the river was easy on its smooth stretches, even though hemmed in by great cliffs; but cascades plunge over ledges where the most resistant rock layers are not yet cut through, and rocky rapids obstruct the channel where side canyons deliver heaps of bowlders to the main river. After many perils the party came out to the open lower country on the west.

Plateaus interrupted by narrow canyons are, as a rule, occupied only on their upland surface. The elevation of the upland is an advantage in the torrid zone, where the high temperatures at sea level are willingly exchanged by civilized races for a more moderate temperature at altitudes of several thousand feet. But in the temperate zone a high plateau is at a disadvantage from the rigor of its winters, as well as from its difficulty of access.

The canyonlike valleys are obstacles to movement; they serve as barriers (except to birds and winged seeds) between the uplands on each side. They are seldom inhabited, unless by the people of a persecuted tribe, who sometimes take refuge as "cliff dwellers" in the recesses or caves that are often excavated between cliff base and talus top.

105. Dissected Plateaus. — The rugged uplands that extend continuously from New York to Alabama, known as the Catskill, Allegheny, and Cumberland plateaus, may here be treated together under the second name. The whole region is occupied by mountainlike hills and spurs, built of nearly horizontal rock layers and separated by numberless deep valleys that have been eroded by the rivers and their branching streams. The hilltop view generally discloses a rather even sky line, which may be taken to mark a plateau surface that once extended over the whole region, before the branching valleys were carved.

The Allegheny plateau is now thoroughly dissected by its streams. It is evidently in a more advanced stage of change than a plateau that has only a few narrow canyons. The altitude of the original upland in West Virginia (roughly 2500 or 3500 feet) has been great enough to permit the erosion of valleys 1000 feet or more in depth; hence some of the plateau remnants fairly deserve the popular name of "mountains," locally applied to them.

Many resistant sandstone layers stand out in cliffs from ten to fifty feet high. As the layers are nearly horizontal, the cliffs run in bands around the spurs of the great hills, but are usually hidden by the heavy forest that

covers much of this region. The weak strata occupy the intervening slopes, covered with a thin stony soil and supporting forest trees. The hills and spurs are all very much alike, for they have been dissected by similar streams. Every side valley resembles its neighbors; all the members of a local tribe of small streams cascade down over the same number of fall-making strata in their descent to the larger rivers.

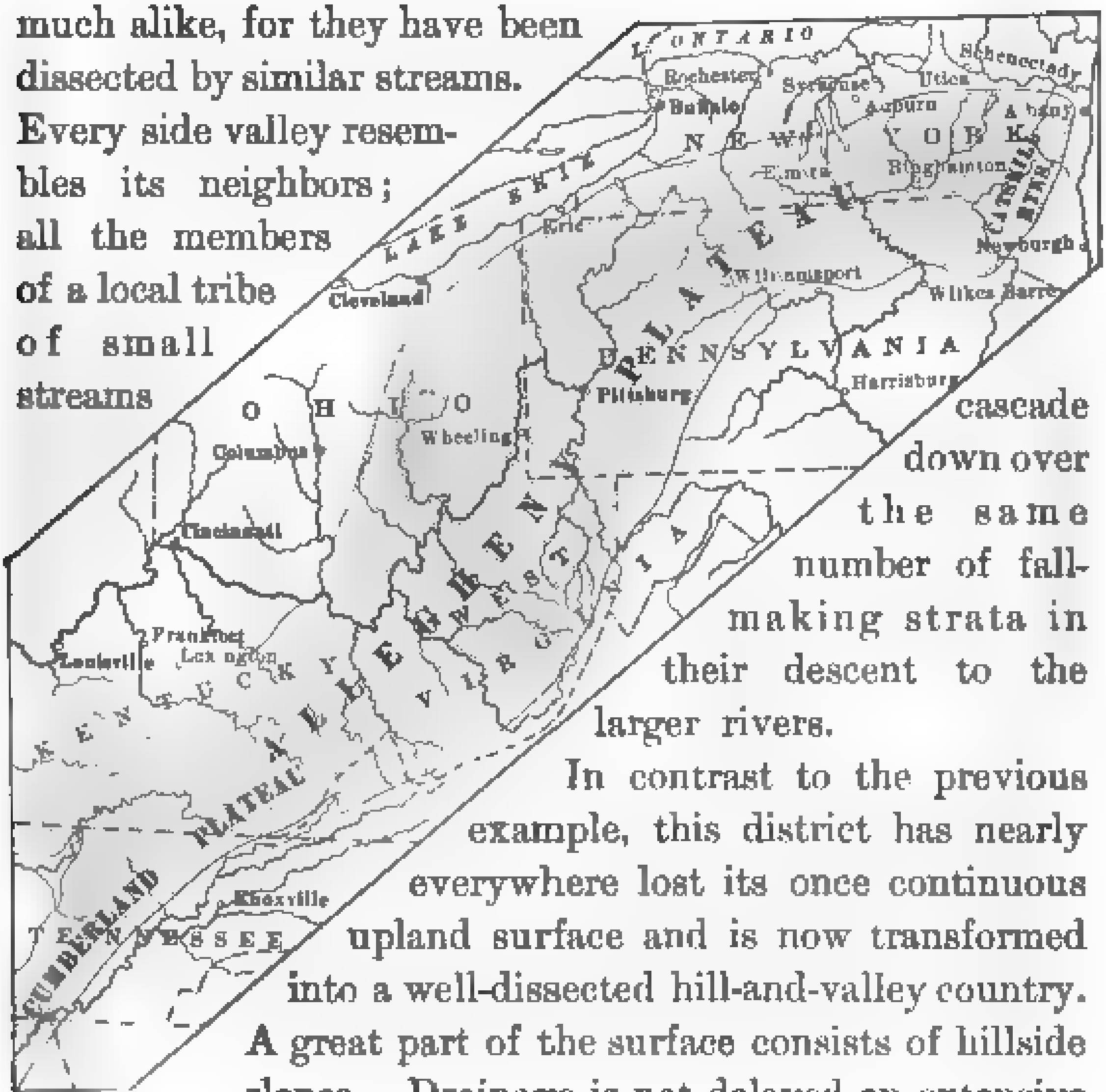

Fig. 78
The Allegheny Plateau

In contrast to the previous example, this district has nearly everywhere lost its once continuous upland surface and is now transformed into a well-dissected hill-and-valley country. A great part of the surface consists of hillside slopes. Drainage *is not delayed* on extensive uplands; but at times of rain or winter thaws water is quickly shed from the hills, and the main streams rise rapidly in destructive floods.

The forests retard but do not prevent the wash of waste from the steep slopes; a great load of waste is delivered by the side streams to the rivers.

What parts of what states are occupied by the Allegheny plateau? Which state has the greatest part of its area in the plateau? What cities can you name in that state? How far is it from the Catskill mountain district to the Cumberland plateau district?

As a whole, the Allegheny plateau is so rugged that its population is small, being generally found on isolated farms

Fig. 79. Canyon of Kanawha River in Allegheny Plateau, West Virginia

upon the disconnected uplands, in villages and occasional small cities in the valleys, or gathered about mines or other industrial works. The isolated hilltop farmers cannot afford to construct and maintain good hillside roads; it is difficult to haul upland products down bad roads to village markets or to railroad stations, and it is doubly difficult to haul supplies up to the farms. Life on the uplands is laborious.

The hillsides are generally too steep for cultivation; if cleared, the soil is rapidly washed away. Wild animals,

such as deer and bear, almost exterminated from the lower country on the east and west, still find refuge here; small game is abundant, and hunting is almost as much of an occupation to the "mountaineers" as farming.

The forests supply lumber to the more thickly settled communities on the east and west. The numerous coal seams (vegetable deposits in ancient marshes, now members of the great series of horizontal strata that build the plateau) are well exposed on the sides of the deep-cut valleys, and are now extensively mined. Iron ore occurs in certain strata. Rock oil and natural gas are found by boring deep wells. It is chiefly in connection with the industries dependent on these important products that a larger population is to-day attracted to this rough country. In the earlier history of the United States the dissected Allegheny plateau was (excepting the North Carolina mountains) the most formidable barrier between the Atlantic coastal plain and the open prairies of the Ohio valley.

Intercourse and traffic are still so difficult in the districts of stronger relief, away from the lines of travel, that the people of the Allegheny plateau are slow in acquiring the ways of civilization. Family feuds are still maintained among the "mountaineers" of West Virginia and Kentucky. As the uplands decrease in height westward, and the valleys become more open toward the Ohio river, population increases; but Pittsburg is a city of exceptional size in this region. Its growth in early years was favored by its position with reference to the lower Ohio valley, and in later years by the great stores of mineral wealth in the surrounding country.

106. Mesas. — Broad plains of gently rolling surface, drained by streams in wide-open, flat-floored valleys, are sometimes overlooked by flat-topped "table mountains" of horizontal rock layers. Neighboring tables are of nearly uniform height, each one being capped by the same kind of cliff-making rock layers and flanked by a sloping talus. In the western United States tables of moderate height are often given the Spanish name *mesa* (table; pron. *may-sa*); while the smaller mesas are known by the French name *butte* (target or landmark; pron. *bewt*).

Mesas and buttes of this kind are all that now remain of a plateau that once spread far and wide over the region. The open space between the mesas has been produced by the widening of the valleys, so that their floors now occupy a great part of the surface. The original level of the plateau may have been much higher than the tops of the mesas, for the uppermost strata may now be completely washed away. A region of this kind represents an approach to what may be called the old age of a plateau, when even the mesas will be worn away, leaving an unbroken plain. It is very unlike the youth of the plateau, when the uplands were broad plains and the valleys were narrow canyons.

The plains of western New Mexico are surmounted by numerous mesas or plateau remnants. Settlement here is chiefly limited to the lower lands. The isolated mesas and buttes, rising several hundred feet above the plains, are generally uninhabited.

The mesas of an old plateau are not, like the canyons of a young plateau, serious obstacles to travel; for while

canyons continue for long distances and are everywhere difficult to cross, mesas are generally of moderate length, and many broad passages are opened among them. They are occasionally occupied as natural citadels by barbarous tribes.

One of the most remarkable remnants of an old plateau is the so-called Enchanted mesa of western New Mexico.

FIG. 80. The Enchanted Mesa, New Mexico

It rises more than 400 feet above the surrounding plain, and although no longer inhabited, it was once occupied by a small tribe of Indians, who found safety on its almost inaccessible summit.

Other mesas in New Mexico and Arizona are still occupied by Indians, whose compact groups of houses on the upland cannot, at a little distance, be distinguished from the rock walls of the cliffs. The Indians cultivate small patches of corn on the lower ground, but they have not ventured to build villages there for fear of attack from more warlike tribes.

In the interior of British Guiana gigantic remnants of an old plateau rise above the surrounding lower country. Huge mesas are rimmed round by almost inaccessible cliffs that stand above long talus slopes. One of the highest is Roraima, whose broad table is more than 2000 feet above its base. It is uninhabited, and until recently had never been ascended.

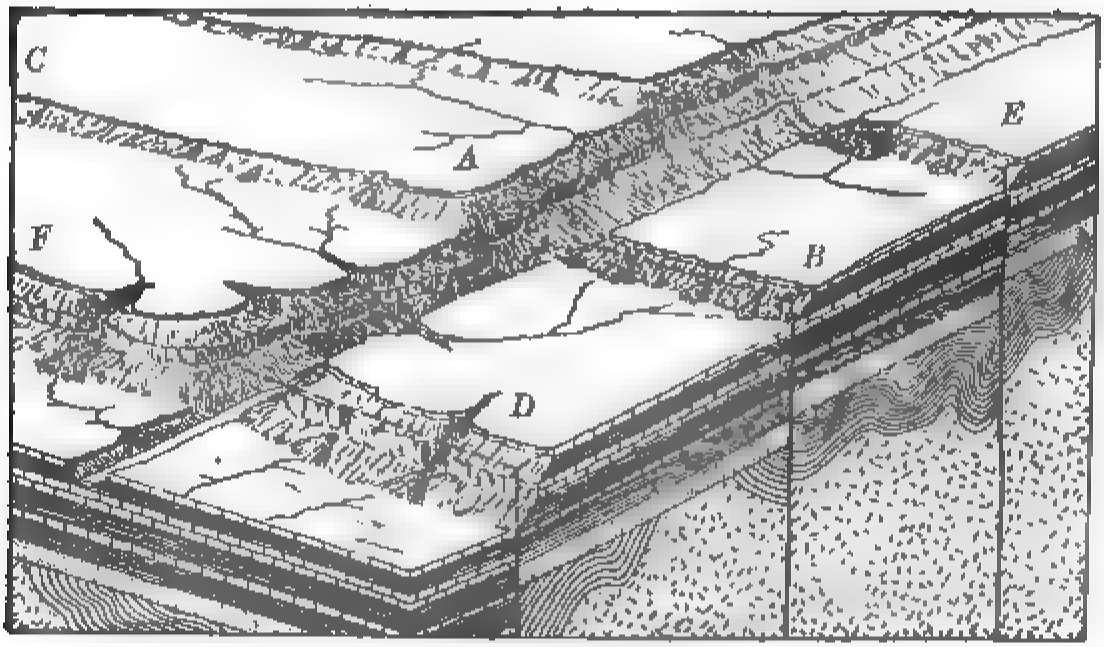

Fig. 81. Broken Plateaus

107. Broken Plateaus. — The plateaus of northern Arizona, of which the Sheavwits already described is one, stand in a curious relation to one another. East of the Sheavwits comes the Uinkaret, presenting the same upland (diversified by volcanic cones and lava flows), and exposing the same succession of cliffs and talus slopes in the canyon walls; but the Uinkaret stands about 1800 feet higher than the Sheavwits. The two are separated by a high and ragged cliff, or escarpment (*CA*, Figure 81), known as Hurricane ledge, facing westward.

The section exposed in the canyon (*A*, Figure 81) shows that the cliff stands on the line of a great north-and-south fracture, which divides the whole mass of strata into two blocks, the eastern block (Uinkaret) being lifted nearly 2000 feet higher than the western (Sheavwits). Several other similar plateau blocks are found in this region. The displacement of the blocks is

Fig. 82. Hurricane Ledge, a Dissected Fault Cliff

clearly represented in the section on the right front of the diagram, Figure 81, under the letters *D*, *B*, *E*.

The western boundary of the Sheavwits plateau (*FD*, Figure 81) is one of these cliffs of displacement, 2000 or 3000 feet high. It is cut by gigantic ravines, from which great volumes of rock waste are washed out.

Fractures of this kind, on which adjacent blocks of land are displaced, are called faults. The cliffs that originate on the broken face of the uplifted blocks are called fault cliffs. They are in time more or less worn back by

weathering and by the growth of ravines, such being the present stage of Hurricane ledge; and they may then be called dissected fault cliffs.

The forces by which the plateau blocks have been broken and lifted have not been fully explained. It is probable that violent earthquakes accompanied the production of the fractures, and that the displacement of the blocks was accomplished by many small movements, each causing a moderate earthquake.

QUESTIONS

SEC. 96. Describe the natural processes in operation on a mountainous district bordering the sea. Consider the relation of such a district to habitation. Give an example.

97. Describe a narrow coastal plain. Describe its valleys and their lateral ravines. Explain their origin. What can be inferred as to the future form of such a plain? as to its past form? How can the origin of such a plain be accounted for? Define baselevel, and state the relation of rivers and valleys to baselevel. Describe a narrow coastal plain in Scotland; in Oregon; in Mexico.

98. Describe a broad coastal plain. What is meant by relief? Describe the coastal plain of the South Atlantic States as to form; as to soil; as to industries. Why are its soils arranged in belts? Compare it with the narrow coastal plain of Scotland. What products are derived from it?

99. Describe a belted coastal plain. What is the origin of its form? What is a cuesta? Describe the course of the streams with respect to a cuesta. Describe the belted coastal plain of New Jersey.

100. Describe an embayed coastal plain as to hills, valleys, and bays. Explain its origin. How has the depression of the region affected the form of the coast line? Describe an example of this class. Describe its effects on the distribution and occupation of its population; on the location of roads, villages, and cities.

101. Where may falls be expected in rivers that cross coastal plains? What is the cause of the falls? What is the fall line? Where are cities likely to be situated on the rivers of coastal plains? What cities lie on the fall line of the Atlantic coastal plain?

102. Describe the Great plains of the central United States as to origin, form, climate, vegetation, and industries. Describe the extension of these plains into Canada as to climate and vegetation. Describe the plains of western Siberia as to form, climate, and population. Why are the valleys in these plains shallow? What is the relation between nomads and inland plains?

103. What is a belted inland plain? Describe an example from Wisconsin. Explain its origin. Where may some other inland belted plains be found?

104. Compare plains and plateaus. Describe a canyon as to form and origin. Compare the form of the canyon walls as shown in the diagrams of a narrow and a widened canyon. Explain their differences. What is the relation of strong and weak rock layers to form? Describe the movement of rock waste in a canyon. Describe the plateaus of northern Arizona. Describe the Colorado river and its canyon. Why is it difficult to follow the river? What is the value of plateaus to habitation? of canyons as barriers?

105. What is a dissected plateau? Describe the Allegheny plateau as to location, extent, altitude, and form. Describe the hillsides; the streams; the drainage; the industries; the products of this plateau. What is the condition of its people?

106. Describe mesas and their surroundings. How are mesas formed? Compare a mesa and a canyon. Compare the plateaus of northern Arizona, the dissected Allegheny plateau, and the mesa district of New Mexico. Describe the Enchanted mesa; Roraima.

107. What is meant by broken plateaus? Describe the broken plateaus of northern Arizona. How are they separated? What is a fault? a fault cliff? a dissected fault cliff? What is the relation of earthquakes to broken plateaus?

CHAPTER VI

MOUNTAINS

108. Mountain Ranges.—The peaks and ridges of mountains are generally grouped in belts of much greater length than breadth, called mountain ranges. When several ranges are grouped together they constitute a mountain chain. Unlike plains and plateaus, in which, as has been stated in the preceding chapter, the rock layers are nearly horizontal, mountain ranges are belts of disordered structure in the earth's crust. Sometimes the strata are broken, displaced, and tilted as if gradually disturbed by some great uplifting force from beneath; sometimes the strata are bent and folded, as if slowly compressed by some irresistible crushing force from one side.

The origin of the forces which produce mountains is not fully understood. One of the most ingenious and satisfactory theories accounts for many ranges as great disorderly folds formed in the crust of the earth, which is thought to wrinkle here and there as it very gradually settles down on the slowly cooling and contracting interior.

Streams carve deep valleys in the uneven surface produced by mountain upheaval. Mountains as we see them are therefore the result of deforming forces which slowly

raise the mountain belt to great height, and of eroding forces which still more slowly wear down the uplifted belt by carving valleys in it.

FIG. 83. A Mountain Peak

109. Block Mountains. — In southern Oregon and the adjoining parts of California and Nevada there are many long narrow mountain ridges, extending about north and south. Each ridge is a few miles wide, ten to forty miles

long, and 1000 or more feet high. The ridges are steep or cliff-like on one side, of gentler slope on the other, and are separated by flat trough-like depressions of varying breadth and depth. A general view of the country shows that the entire region was once a plain, but that it has been gradually broken into long narrow blocks, and that the blocks are tilted one way and the other, so that their uplifted edges form the mountain crests.

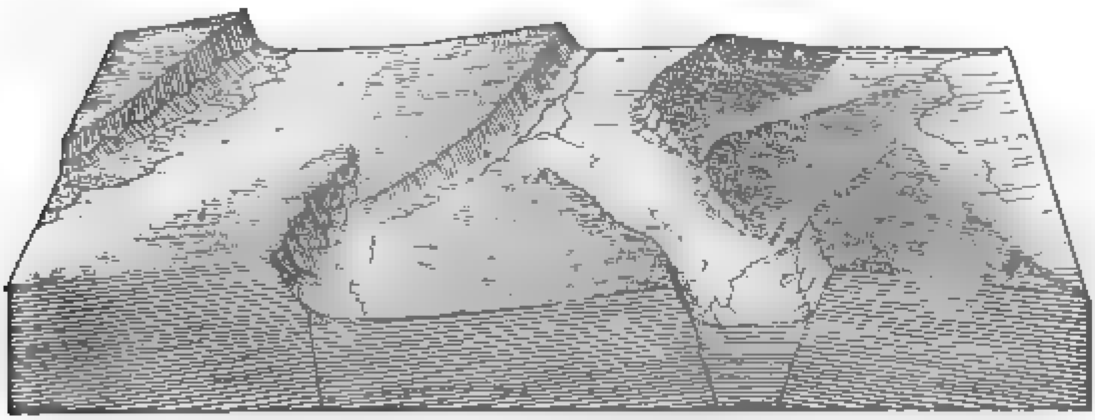

FIG. 84. Block Mountains

Which block mountain is completely shown in Figure 84? How does it end? (Note: the space included in the figure is too small to show the whole length of most of the mountains; the northern part of some and the southern part of others are cut off.) Describe a large block mountain; its crest line, its cliff face, its back slope. Where could it be best ascended?

Some of the ridges still preserve the form of the tilted blocks, hardly changed by weathering; their sloping backs are smooth; their cliffed fronts have little talus at the base. Others have shallow gullies worn down the back, while the cliffs are indented by ravines, and every ravine has a fanlike deposit of rock waste spread out beneath it;

between the fans the cliffs have a distinct talus slope at their base. Yet the mountain blocks of Oregon are, on the whole, so little worn that they must have been broken and tilted recently in the earth's history.

Earthquakes are not infrequent in this region; hence it is believed that the tilting of the blocks is still in progress from time to time; a movement of even a few inches would suffice to cause earth tremors, while a sudden start of a foot or more would produce a violent and destructive shock for many miles around, gradually fading away at greater distances. There is no sign that volcanic action has any connection with the fractures and earthquakes of this region.

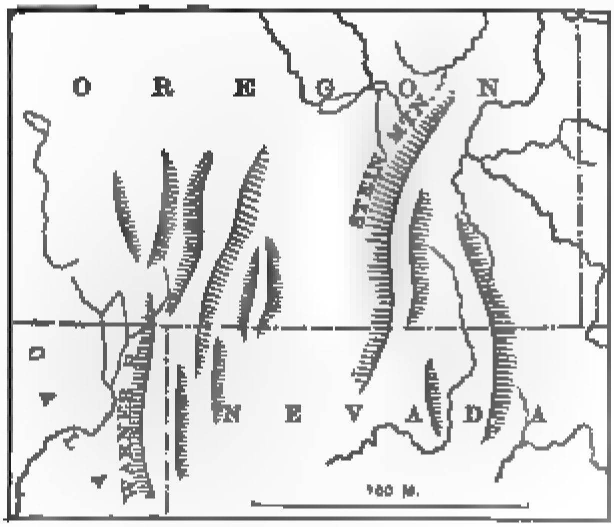

FIG. 85 Mountains of Southern Oregon

The drainage of the block mountains is very simple, for the streams follow the slopes produced by the tilting of the blocks. The smaller wet-weather streams flow down the slopes of the ridges. Larger streams flow along the troughs in the direction of their slant to the deepest depressions, and there form shallow lakes and marshes. The finer waste from the ridges is spread evenly over the lower parts of the troughs, concealing their rocky floor.

Certain features of the region depend on its arid climate. The rainfall is light (fifteen inches or less a year), for the Sierra Nevada and Cascade ranges on the west take most

of the moisture from the Pacific winds. Few of the lakes are filled to overflowing; they discharge their water supply by evaporation into the dry air. Most of the lakes are therefore saline, and the plains of fine waste about them are barren.

In dry seasons the lakes shrink; some of them disappear, leaving smooth floors of sun-baked clay. The bottom of the troughs elsewhere and the lower slopes of the ridges are clothed with bunch grass and sagebrush; the ridge slopes, receiving more rainfall than the lower lands, support scattered cedars, and the higher crests bear forests of pine and spruce.

Although the ridges are of moderate height, they repel the few settlers in the region, whose ranches are all found in the troughs. The thin grass supports scattered herds of cattle, and the streams suffice for a little irrigation. Thus even in these low young ridges the effect of mountains on climate, distribution of vegetation, and location of settlements is well shown.

110. Dissected Ranges. — In Nevada and the adjoining parts of California and Utah there are many north-and-south mountain ranges from twenty to eighty miles long, and from five to twenty miles wide. Their summits rise from 5000 to 7000 feet above the plains. Their crests are notched and uneven; their slopes are varied by well-carved spurs between deep valleys. The troughs between the ranges contain long slopes of gravelly waste that have spread out from the valleys when the streams are flooded. As compared with the ridges of southern Oregon, these

ranges are larger and more dissected. They possess more of the beauty and variety of form generally found in mountains.

The ranges of Nevada, like the ridges of Oregon, seem to have been formed by the uplifting of long blocks of the earth's crust; but in Nevada the blocks must have been

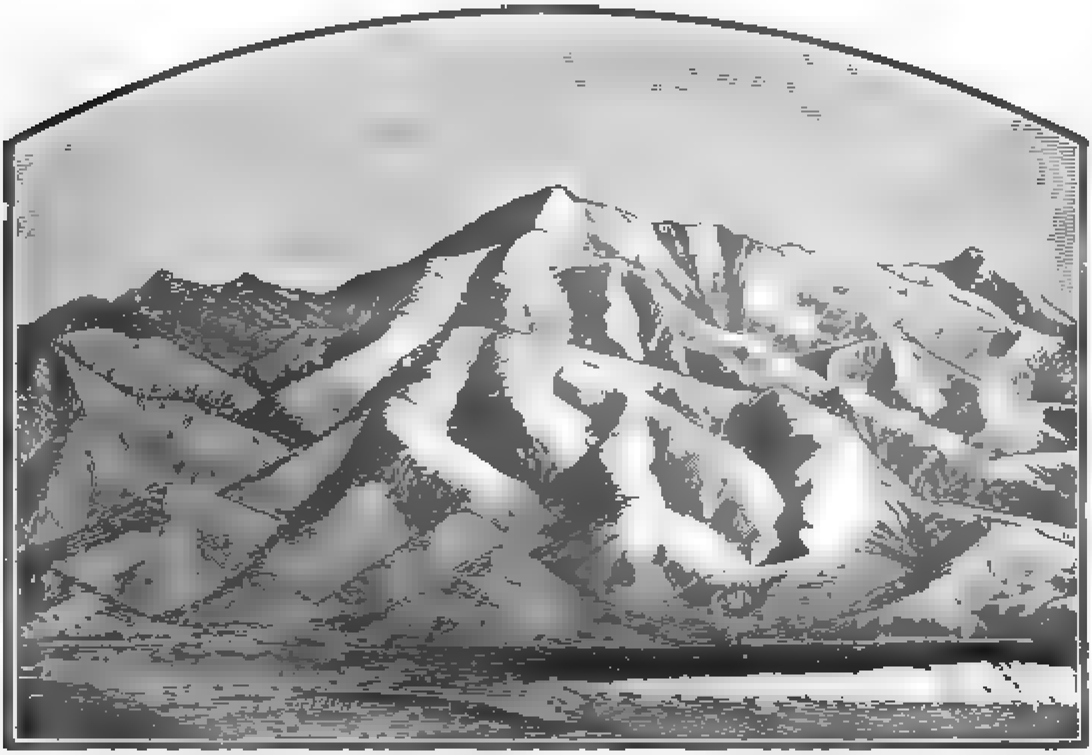

FIG. 86. A Dissected Mountain Range, Utah

larger and the uplifting greater; and the uplifting must have begun earlier than in Oregon, for the work of dissection by streams is here much further advanced. The ranges of Nevada are thoroughly or maturely dissected. Yet, as in Oregon, occasional earthquakes show that the mountains are still growing.

The higher ranges in Nevada exhibit more distinctly than the smaller ranges of Oregon the lower temperature,

with greater cloudiness and rainfall, that prevails on the mountains as compared with the plains between them. The rainfall on the plains is light, but storm clouds often gather round the peaks while the sun shines elsewhere. When the clouds dissolve, the mountains have been refreshed by rain or whitened with snow, while the plains may be as dry as before, except where the turbid flooded streams rush out from the mountain valleys. The streams generally wither away on the gravelly plains. Settlements in Nevada are therefore commonly limited to a belt around the mountain base, where the streams may irrigate fields. Some of the ranges contain valuable ores; hence mining towns have sprung up in their valleys.

111. Folded Mountains. — The Jura mountains, along the border of France and Switzerland, occupy a belt of country where the rock layers, once horizontal, have been slowly pressed into a series of wavelike folds. The mountains consist of a number of parallel ranges and valleys trending about northeast and southwest. Each range consists of a series of rock layers bent upward like an arch; each valley is underlaid by the same series of layers bent downward like a trough. Some of the uppermost layers have been weathered off from the crest of the arches; the edges of the harder layers remain in flanking ridges. Waste from the arches has accumulated in the troughs, flooring them with gravel and sand.

The rock layers of these mountains contain sea fossils; the layers must originally have been horizontal strata on the floor of an ancient sea. Since then they have gradually

been pressed and folded into their arch-and-trough structure by a powerful side pressure.

The drainage of the Jura mountains is, for the most part, like that of the Oregon ridges in following the slopes of the deformed surface. Short streams run down the sides of the arches, cutting ravines on the slopes, as shown in

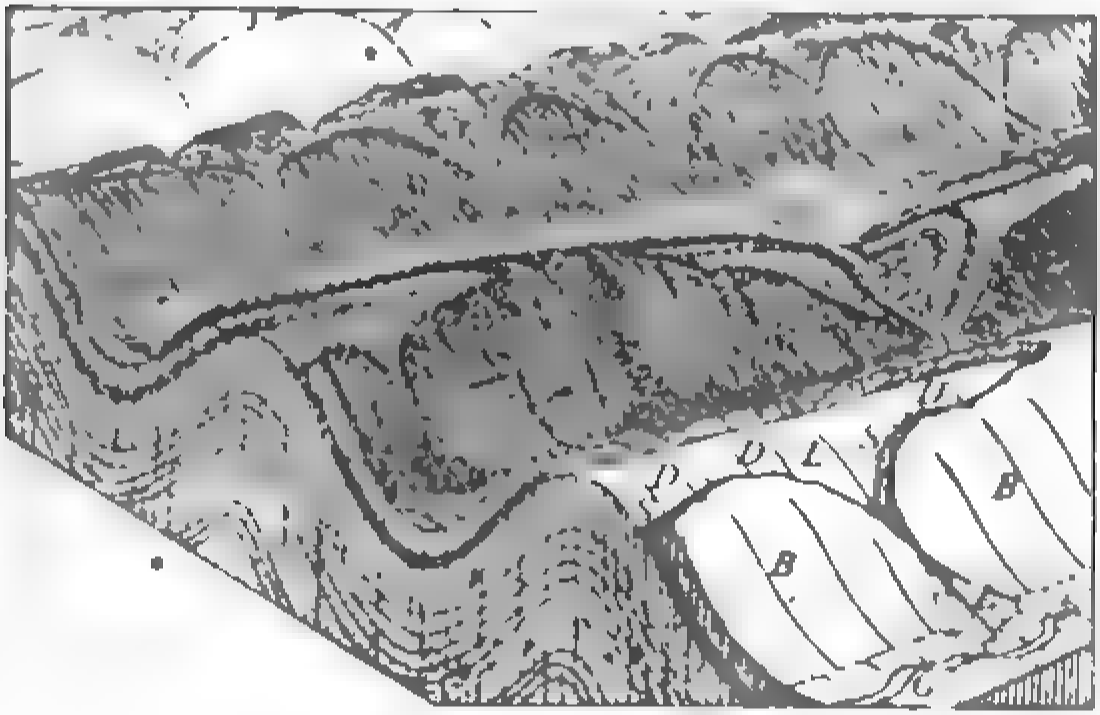

FIG. 87. Diagram of the Jura, a Folded Mountain Range

the unshaded foreground of Figure 87. Larger streams gather on the trough floors and escape at one end or the other as opportunity offers. Here and there a stream cuts across an arch, wearing a deep gorge from one trough valley to the next, and exhibiting the arched structure, as in the middle ridge of Figure 87.

Where are the Jura mountains? How many arches are shown in Figure 87? How many troughs? What is their trend? How many cross valleys? If you were traveling there, where would you go to

see the arched rock layers? Where does the topmost layer lap over an arch? What forms result where the topmost layer has been partly worn away? Describe the course of some of the small streams that rise on the top of an arch.

As in all mountains of distinct relief, the form of this range exercises a strong control over the distribution, occupation, and movement of the population. The valley floors are well settled; villages often lie near the mouths of transverse gorges. Roads are generally limited to the lengthwise and crosswise valleys. Byways and footpaths lead to the upland fields and pastures. Little villages are sometimes found on the tops of the broader arches. The steeper slopes are generally forested.

112. Lofty Mountains.—Lofty mountain ranges, like certain parts of the Rocky mountains, but better represented by the Alps, the Caucasus, and the Himalayas, exhibit a remarkable variety of peaks, ridges, ravines, and valleys. Their higher central peaks usually consist of the most resistant rocks, surrounded by slanting layers that rise in great ridges.

These majestic forms usually depend as much on the deep erosion of great valleys by streams as on their lofty uplift. Unlike the simple tilted blocks of Oregon, or the orderly folds of the Jura, the greater ranges show little or nothing of their original form.

The discovery of marine fossils in the bedded rocks of high Alpine ridges toward the close of the eighteenth century was received with great astonishment by the scientific men of the time. The occurrence of fossils in so elevated a position was one of the first generally accepted proofs of the changes that have gone on in the past, by

which the present form of the earth's surface has been fashioned. But not until the nineteenth century had well advanced was it generally understood how much more the form of lofty mountains depends on processes of land sculpture than on forces of uplift.

113. Peaks and Ridges. — The height of lofty mountain summits is due in great part to the uplift that the whole

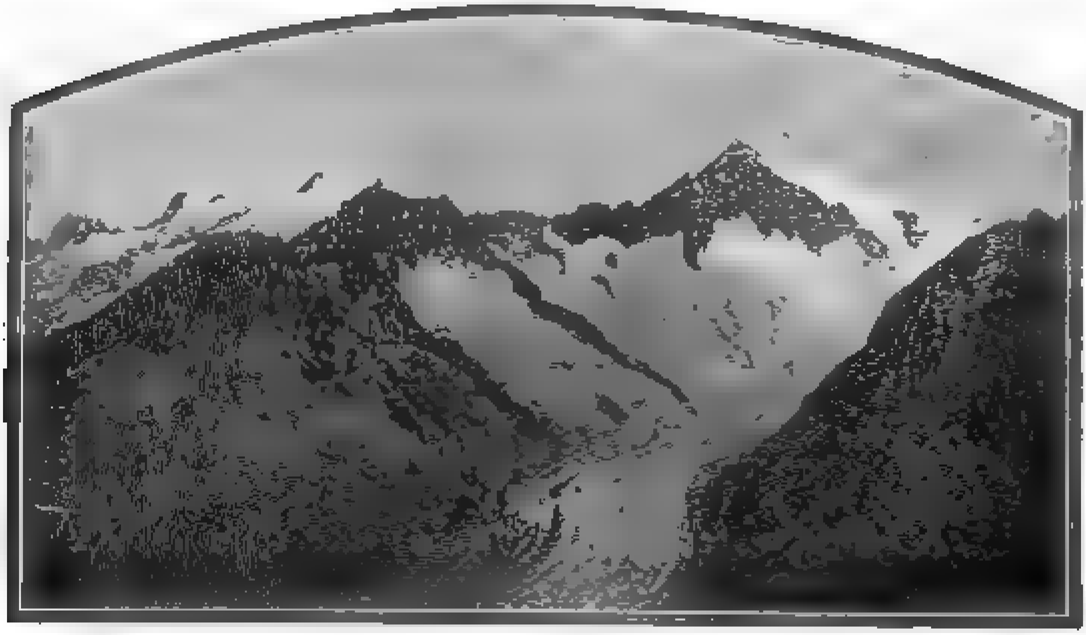

FIG. 88. Peaks of the Central Alps

range has suffered, but in part also to the success of the stronger rocks in resisting the attack of the weather, under which the weaker rocks have greatly wasted away. The waste that is shed from the peaks and ridges creeps and washes down into the valleys, usually leaving the loftiest summits bare and sharp. Deep valleys are eroded by the streams between the ridges, and steep ravines are worn in the slopes and spurs. Thus mountain forms are chiefly due to weathering and stream carving.

The bare rocky peaks and ridges, rising into the cold upper atmosphere, far above the limits of vegetation, are silent deserts.. The stillness is broken only by the rush of storm winds and the roar of rock falls and snowslides. Not less barren are the snow fields and the talus slopes on the higher mountain flanks, and the slanting reservoirs of ice and snow in the upper valley heads, from which

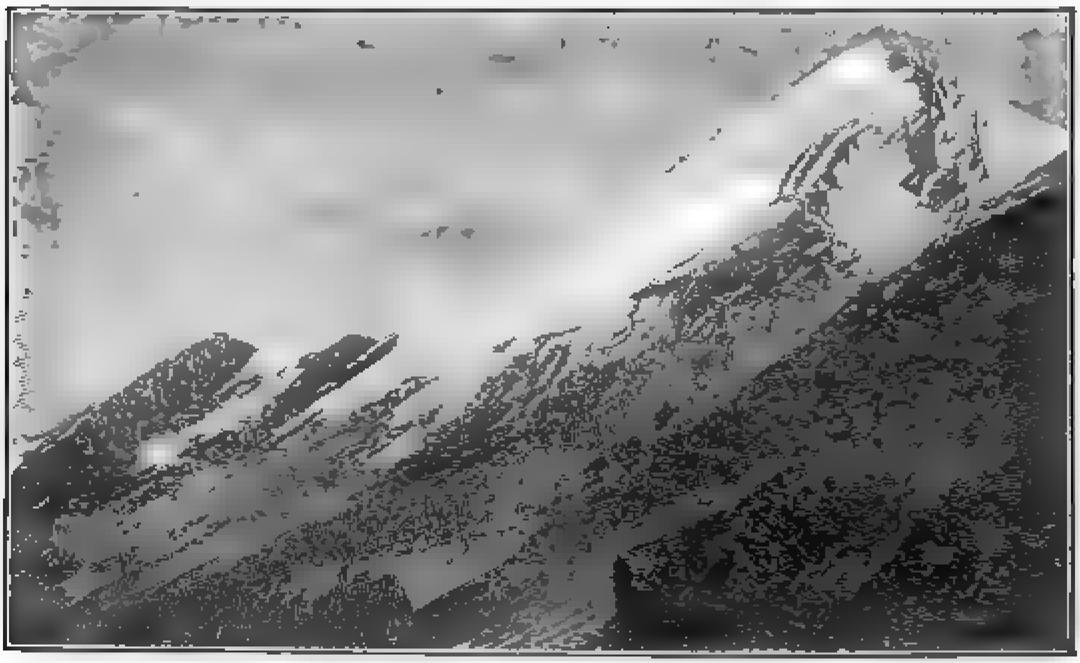

FIG. 89. An Alpine Peak of Slanting Layers

slow-moving ice streams, or glaciers, creep down to the lower valleys. The lower slopes are generally forested.

Many summits in the Alps are so sharp that they are called needles or horns. They rise as almost inaccessible peaks between the growing valley heads. Mt. Blanc, the highest mountain of the range (nearly 16,000 feet), is of domelike form with a heavy snowcap; it is not yet sufficiently dissected by valleys to take the form of sharp ridges and peaks.

The Selkirk range of the Rocky mountains in Canada has steep and bare summits surmounting the long lower slopes. The slopes are covered with waste that is slowly creeping and washing into the valleys, to be borne away by the streams. Having an abundant snowfall, the range bears extensive snow fields and glaciers. In the Rocky mountains of Colorado snow is less plentiful, snow fields are small, and glaciers are wanting. Long slopes of creeping waste cover the mountain flanks far up toward the summits, as in Plate I; craggy peaks of sharp form are less common than in the Selkirks or the Alps.

114. Climate of Mountains. — On extensive plains the climate—especially the temperature and rainfall—shows little variation from place to place, being nearly uniform for hundreds of miles together. On the average, one must travel from thirty to sixty miles poleward to find a difference of 1° in mean annual temperature. The same difference is found on mountains by an ascent of only 300 feet. Many mountains rise so high that they receive snow while rain falls on the surrounding lower lands. Lofty mountains are therefore usually clothed with snow on their higher slopes.

Broad plains may have only a scanty rainfall over hundreds of miles together. On mountains the rainfall rapidly increases with elevation, although less may fall on very lofty summits than at heights of from 5000 to 10,000 feet. Not only because they are high, but also because they receive much rain and snow, high mountains are usually the sources of large rivers.

The small changes of form and climate over broad plains make the conditions of life nearly the same over great areas. A great diversity of form and climate is found in mountains within small distances, and strong contrasts are crowded close together.

115. Mountains as Barriers. — High mountains serve as barriers separating the climates and the populations of their opposite sides. The windward (eastern) slope of the equatorial Andes has a moist climate because the damp winds from the Atlantic, ascending and cooling, give forth a heavy rainfall there; the western slope has a dry climate because the same winds, descending and warming by compression, not only give forth no more rain, but eagerly take up whatever moisture they find on the way. The eastern slope is densely forested; the western slope is for the greater part a desert, except in valley floors watered by streams.

Moist winds from the Pacific give a plentiful rainfall on the windward (westward) slopes of the Sierra Nevada and the Rocky mountains of the United States. The same winds, descending on the eastern or leeward slopes, become in winter unseasonably warm and dry, evaporating the light snow of the plains and laying bare the dry tufts of grass, greatly to the advantage of the cattle feeding there. The dry wind is called the chinook. A similar wind occurs in the northern valleys of Switzerland, where it is called the foehn.

The great populations of India and China, representing different races, are separated by the Himalayas and other ranges in southern Asia. The two peoples are thus so

well held apart that neither of them has had any important influence on the other. Lofty mountain ranges thus rank with the oceans in separating the inhabitants of the lands.

When low countries on opposite sides of a high range are occupied by different peoples the mountains commonly serve as a natural boundary between them. The mountain range as a whole may serve as a rough boundary between uncivilized nations; but between civilized nations the crest line dividing the rivers of the opposite slopes is often accepted as a more precise boundary, as in the Pyrenees between France and Spain, where the river divide is generally adopted as the national divide.

When the river divide departs from the main range that it was supposed to follow before the mountains were explored, the boundary question may give rise to dispute, as recently between Argentina and Chile, where a number of Pacific rivers rise on the pampas of Patagonia and cut through the Andes in deep gorges.

The difficulty of crossing lofty ranges gives great importance to the notches, or passes, in their central ridges, through which travel and traffic may go with less effort than over their peaks. The heavy snows of the winter may close the passes for several months. In earlier centuries, when the passes were traversed only by paths, houses of refuge were often maintained on the summit by monks, as on the famous pass of St. Bernard in the Alps.

It is mostly within the last hundred years that well-planned roads have been constructed over the chief passes of various mountain ranges. The roads enter the mountains along the larger valleys and then zigzag up the

Plate VII. A Railroad rounding a Spur of Mt. Ouray, Colorado

steeper slopes. They are carefully laid out so as not to exceed a certain moderate grade,—about five feet in a hundred. Certain passes are now crossed even by railroads, the ascent from the valleys being most ingeniously made by curves and "loops." Sometimes the last part of the ascent is avoided by tunneling the ridge under the pass, it being cheaper in the long run for a railroad to bore through than to climb higher.

When gold had been discovered in California and a new population was making its way there in 1849 and 1850, the mountain ranges in the western United States were so formidable a barrier to travel that many of the emigrants preferred the long voyage by sailing vessel around Cape Horn. Those who went overland suffered great hardships in crossing the mountains by rough trails, and many died on the way. Since then the mountains have been carefully explored, the lowest passes have been found, and several railroad lines now connect the Central States with the Pacific coast.

Mountains are often climbed for the exhilaration that comes from ascending them, and for the glorious view over the peaks and valleys that is gained from the summits. Clubs of mountain climbers have been formed in many countries.[1] They publish narratives of excursions in mountainous regions. The ascent of very lofty mountains, above 16,000 feet in height, is made difficult by the thinness of the air so far above sea level. Fatal accidents sometimes occur, especially when inexperienced climbers try to make ascents of difficult peaks without well-trained guides.

116. Avalanches. — The heavy snowfall of winter often overloads the snow banks on the higher slopes, and great masses of snow slide down to lower levels. Summer melting and rainfall also cause slides, or avalanches (*a-val*, to the valley). Sometimes the snow mass glides along the sloping surface at a moderate speed. Sometimes it leaps from cliffs

FIG. 90. Path of an Ice Fall in the Alps

and falls with a terrible velocity to the valleys below; a violent blast of air bursts outward from beneath, overturning trees hundreds of feet beyond the reach of the snow.

Certain villages in Alpine valleys carefully preserve a patch of forest on the slope above them as a protection from avalanches. Roads and railways on steep mountain slopes must here and there be covered in by long snow-sheds, over which the snow may slide without blocking or injuring the road.

Heavy masses of ice are occasionally detached from glaciers that end on steep slopes, forming "ice falls."

These are even more destructive than avalanches of snow. An ice fall over 5,000,000 cubic yards in volume broke from a glacier on the slope of a peak in the Alps in September, 1895 (Figure 90; see Figure 89, from a photograph taken before the fall). It slid down a steep slope two and a half miles long, gathered about 1,300,000 cubic yards of rock waste on the way, and then rushed across the valley floor, dashing far up the opposite slope and falling back again, like a wave from a cliff. A bench on the path of the sliding mass caused it to leap forward, clear of the ground; then, as it fell, the air beneath was violently driven away, blowing out fragments of ice and rock and breaking down trees hundreds of yards distant (shown by arrows turned to the right, Figure 90).

117. Landslides on Mountain Sides. — In deep and narrow valleys among mountains the side slopes are sometimes cut so steep that great rock masses may be loosened from the walls and slip to the bottom, forming landslides.

A landslide in the Alps in 1898 destroyed a few of the houses on the edge of the village of Airolo, near the southern entrance to the great St. Gotthard tunnel. The scar left by the falling mass is still distinctly visible high up on the mountain side; the fallen rock, greatly shattered, spreads forward toward the stream in the valley floor. Had the slide taken a course a quarter of a mile farther south, it would have destroyed much of the village.

In September, 1893, a great landslide occurred in the deep valley of one of the upper branches of the Ganges in the Himalayas. In three days 800,000,000 tons of rock

fell with deafening noise, darkening the air with dust, leaving a great bare cavity with steep walls several thousand feet high to mark its source, and building a dam nearly 1000 feet deep across the narrow valley floor. A lake gradually formed on the upstream side of the dam and grew to be four miles long before it overflowed, about a year after the slide.

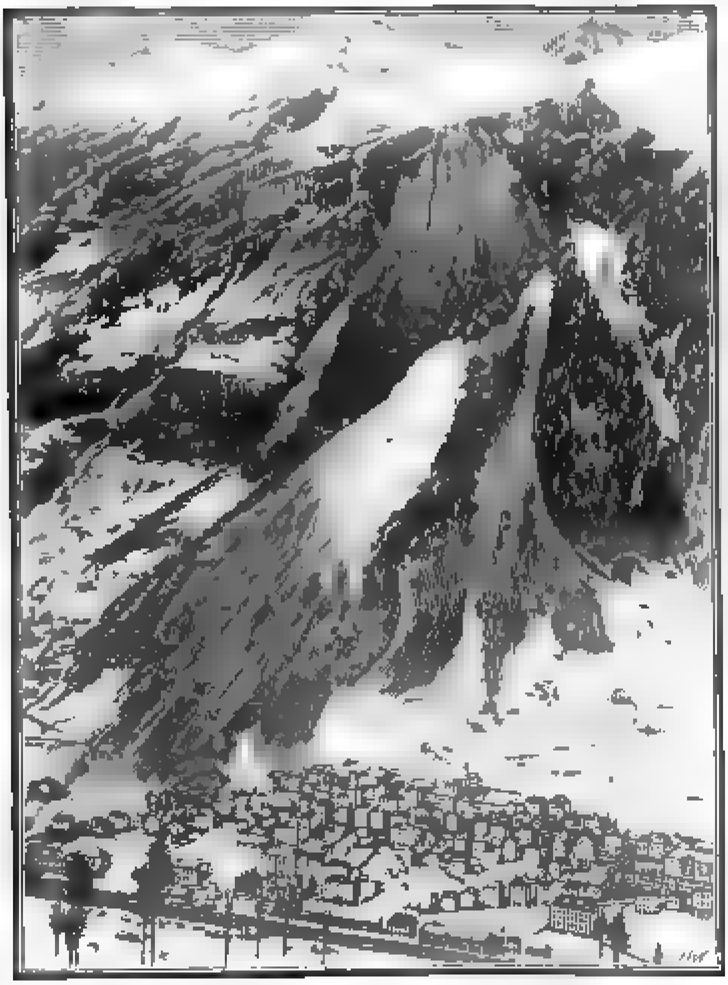
FIG. 91. The Landslide of Airolo, Switzerland

In the meantime the danger that the lake might burst out in a great flood being perceived by the British engineers in charge of the public works of India, the bridges in the lower valley were removed; safety marks were set up on the valley sides, 100 or 200 feet above the ordinary river level, indicating the height above which the flood would probably not rise; and a telegraph line was constructed down the valley from the dam, to give prompt warning of the outburst.

The flood occurred at midnight, August 26–27, 1894. In four hours about 400,000,000 cubic yards of water

were discharged, cutting down the dam nearly 400 feet, flooding the valley to a depth of from 100 to 170 feet, and rushing forward with a velocity of 20 miles an hour. Many miles of valley road were washed away. Every

FIG. 92. A Landslide in the Himalayas

vestige of habitation was destroyed in villages along the upper Ganges; but so well was the notice of danger given that only one man lost his life, and that because he would not heed the warning. Under a less intelligent control, thousands of people must have perished in such a catastrophe. The remains of many other landslides are found in the valleys of the Himalayas.

118. Valleys among Mountains. — One of the strongest characteristics of thoroughly dissected, lofty mountains is the activity with which the rock waste is weathered from the peaks and cliffs, moved down the precipitous slopes,

FIG. 93. The Himalaya Mountains

swept by flooded torrents down steep ravines, and washed by streams along the larger valleys and out upon the adjoining lowlands. The waste seems everywhere to be streaming (as the long-lived mountains might say) down

from the peaks and ridges. The carving of valleys in the mountains has been accomplished by the long duration of these active processes for ages past.

The rock waste consists of angular fragments as it falls from the cliffs and creeps down the slopes. The angles are worn off as the waste is rolled along in rapid torrents, and after traveling thus for a few miles the fragments are well rounded, becoming smaller and smaller the farther they are swept along the stream bed. The fine grains that are worn off from the angles of the larger fragments are borne along more quickly than the larger pebbles and cobbles.

A torrent that receives much coarse waste from a steep-sided ravine frequently sweeps so much of it into the main valley that it cannot all be carried away by the master river. The coarser part of the waste then accumulates in a conelike form, known as an *alluvial fan*, spreading with even slope from the ravine mouth into the main valley.

Alluvial fans have a steep slope when formed by small torrents bearing a coarse and plentiful load. They have a flat slope when formed by large streams with a fine-textured load. They may grow to great size, with a radius of five or ten miles, in large valleys.

Large fans drive the master river against the farther side of its valley, where it undercuts the valley wall. The fan still growing, the river may be obstructed and thus required to spread over the valley floor upstream from the fan, forming a shallow lake, while on the downstream side the river descends in rapids over the coarsest bowlders brought down by the torrent.

How many fans are shown in Figure 94? Where has their material come from? How has it been brought? What effect have they on the course of the main river?

A torrent frequently changes its course on a fan and enters the main river at a new point. Two-Ocean creek, a small stream in the Yellowstone Park, has built a fan that forms a part of the continental divide. Sometimes the stream flows on an eastern radius of the fan to Atlantic creek (Missouri-Mississippi system), sometimes on a western radius, to Pacific creek (Columbia system).

FIG. 94. Alluvial Fans

Villages are often built and fields are cultivated on fans of large size. When the torrent of such a fan is turned on a new course it may flood fields and villages, causing much damage. A valley road crossing the fan is swept away where the torrent then comes upon it, while the bridge over the former channel is useless, now that the torrent has abandoned it.

Accidents of this sort are common in mountain regions. In 1896 a stream entering a lake in Switzerland overflowed its fan with a stony flood fed by a landslip in the head ravine. It laid waste a strip two miles long and over 300 feet wide at the forward end, covering it with a layer of stony mud ten or twelve feet thick. Houses were pushed out of place; a road and a railroad were buried. The advance of this curious flood was sometimes so slow that the grass on the fields in front of it was saved by hasty mowing. For a time all travel had to go by boat on the lake. The people who lived on the fan had some compensation for their losses in carrying the thousands of visitors to and from the scene of the disaster.

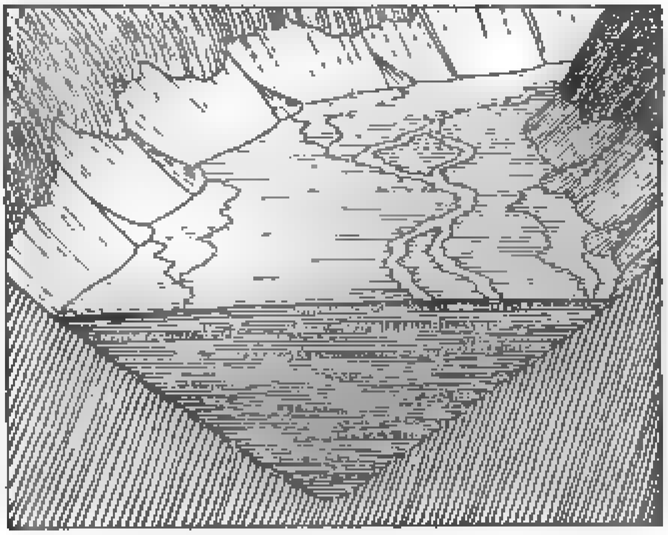

FIG. 95. A Filled Valley with a Flat Floor

Sometimes the steep torrential headwaters wash so much waste from their ravines into the lower valley that the river is unable to carry along all that it receives. Some of the waste then gathers on the valley floor, gradually filling it higher and higher, as in Figure 95. Valley floors of this form are much more easily traveled upon than when the side slopes descend directly to the river bank.

After mountain waste has in this way gathered in a valley to a considerable depth, sometimes measuring several

hundred feet, there may be a decrease in the amount of waste supplied by the headwater streams. This change will permit the river to turn part of its strength to sweeping away some of the waste in its bed, and thus to deepen its channel. As more and more waste is thus removed, a new valley comes to be opened in the flat valley floor, remnants of which then stand in benches or terraces above the new level of the river, as in Figure 96. Terraced valleys of this kind are not uncommon in the Rocky mountain region. Some of the inner valleys of the Himalaya mountains have gravel terraces over 1000 feet high.

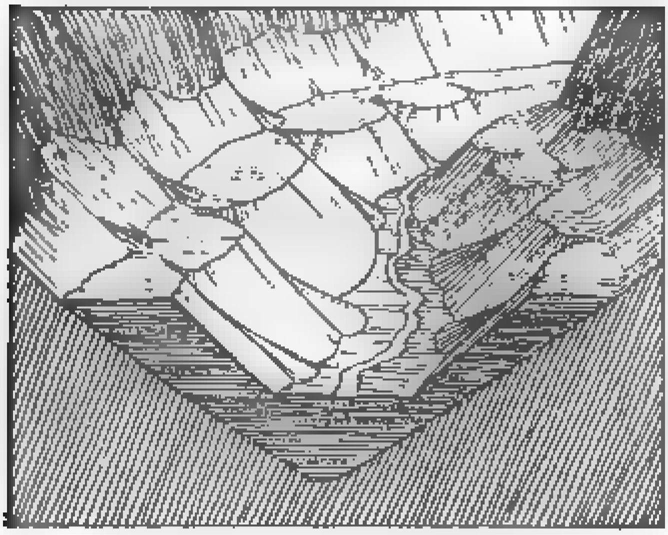

Fig. 96. A Terraced Valley

119. Lengthwise and Crosswise Valleys. — When a river has cut down its valley floor to as moderate a slope as the load of waste that it has to carry along will allow, it may still wear away its banks, first on one side, then on the other. Thus in the course of time the river broadens the valley floor. This is especially true in a valley that is worn down along a belt of weak rocks parallel to the general trend of a mountain range, for these rocks weather and wash away at a comparatively rapid rate.

The crosswise valleys, by which the rivers of the long inner valleys find outlets through inclosing ridges, are

often narrow and steep-walled gorges, for the ridge-making rocks are resistant and weather slowly. The floor of a crosswise or transverse valley may be hardly wider than its stream; the walls rise steep from the water's edge, leaving little or no room for a road or path on either side.

It is chiefly in the broader lengthwise valleys that mountain peoples dwell. When the outlet valleys are narrow gorges the outer world has for centuries been reached only by passes over the inclosing ridges; but modern engineering skill has sufficed to build and cut roads and railroads through many gorges that were impassable a century ago.

120. Earthquakes of Growing Mountain Ranges. — The process of bending and breaking the rock structures within a mountain mass is certainly very slow, but it sometimes causes sudden snaps and slips of a few inches or a few feet. Tremors then spread in all directions from the seat of disturbance, diminishing in force as they advance. On reaching the earth's surface they are felt as earthquakes, producing more or less destruction. Shocks of this kind are comparatively common in and near most of the lofty mountains of the world.

Earthquake tremors travel through the earth's crust with great velocity, — from ten to forty miles a minute; but, as in the case of water waves, the actual movement of the quaking earth at any point may be only a few inches or a few feet a second, backward and forward. The shocks produced by earthquake waves are most violent at places

directly over the seat of chief disturbance. They may be very faint, causing no damage. They may be strong enough to be felt violently over hundreds of square miles, less distinctly over many thousands, and very faintly (by the aid of delicate instruments) all over the earth.

FIG. 97. Railroad shaken by an Earthquake, Northeastern India

One of the greatest modern earthquakes occurred at the base of the Himalaya mountains in northeastern India in 1897. It was probably caused by some underground movement of mountain growth. It formed several fissures, displacing the land on one side with respect to that on the other, forming a step several feet high. The vibrations of the shock loosened rock masses and soil on steep slopes, causing many landslides, which left

the hillsides bare and clogged the valleys. Thousands of forest trees and a great number of buildings in the central area were broken down by being swayed violently back and forth, although the movement was only a few inches. Streams were obstructed and turned from their courses.

FIG. 98. Land Surface displaced by an Earthquake, Japan

Railroad tracks on the neighboring plains were thrown out of line.

A violent earthquake occurred in Japan in 1891 by which a deep fissure was formed in the earth's crust, and the land on one side of it was lowered with respect to that on the other, as shown in Figure 98.

Earthquakes of moderate violence are still frequent in the Alps, occurring five or ten times a year. Five centuries ago (1348) a violent earthquake in the eastern

Alps caused a great landslide by which a valley was barred across and a lake formed upstream from the slide. Countless thousands of shocks must have been produced during the long ages of mountain growth. The association of earthquakes with the young tilted-block ridges of Oregon, with the more mature mountains of Nevada, and with vigorous ranges like the Alps and the Himalayas, is a natural result of the continued disturbance or growth of the mountains.

121. Human Life in Lofty Mountains. — The people who to-day dwell in the valleys of lofty mountains are in many cases the descendants of races who formerly occupied the adjacent lower lands, from which they were driven by conquering invaders. Inclosed valleys among mountains serve as refuges, where pursuit is too difficult to be profitable. There the weaker race long remains unmolested, holding little intercourse with the outer world and preserving old forms of speech and old-fashioned customs. The invaders occupy the neighboring open country; they engage in traffic with other parts of the world and advance in new ways of living.

122. Subdued Mountains. — There are certain mountain ranges of moderate height in which sharp peaks are absent and bold cliffs are rare. The slopes are of moderate steepness, and rock waste covers them almost from base to summit. Mountains of this kind do not reach upward into a climate very unlike that of their base; and if not in a dry or a frigid region, they may be forest clad to the top.

Plate VIII Grandfather Mountain, North Carolina

The earthquakes that are common in mountains of active growth and the landslides that happen frequently in mountains where the valley sides are still steep are rare or unknown in these mountains of gentler form. Unlike those vigorous and lofty younger forms in which uplift and erosion are still active, the rounded forms of these mountains express subdued strength, as if their high peaks and ridges had been greatly worn away by the long-continued attack of the weather. They may therefore be called subdued mountains.

The Blue ridge and other mountains of North Carolina are good examples of subdued mountains. No sharp peaks tower into the sky. The summits generally rise domelike in rounded outline. Heavy forests clothe their slopes.

Subdued mountains may still have so strong a relief that the people living in their valleys preserve older fashions than those of the more open lower country. This is seen in the homespun clothing and in the primitive manner of living of the North Carolina mountaineers.

The mountains of Wales make another group of subdued forms, but more rugged than the mountains of North Carolina. Here remain some of the descendants of the ancient Britons who were driven from the more open lowlands of eastern and central England by Saxon and Norman invaders, 1000 or 1500 years ago. The Welsh language, therefore, represents the original language of Britain, while the English language is a compound of the speech of the invading peoples from the continent. The Scotch highlanders are clannish because the clans have long lived in secluded glens among the Highlands.

123. Worn-Down Mountains. — In certain parts of the world ancient mountain ranges have been almost completely worn away. Their disordered rocks, once rising in lofty peaks and ridges, and perhaps bearing snow fields and glaciers, have been reduced to an almost plain surface, little above baselevel and everywhere open to settlement. Lowlands of this kind are called peneplains (*pene*, almost).

FIG 99. The Piedmont Belt, Virginia

The Piedmont belt of Virginia, between the Blue ridge and the coastal plain, is in many respects an excellent example of a worn-down mountain range. It is a peneplain, not monotonously smooth, but undulating in graceful swells between gentle depressions. The soil is deep, fine, and fertile, and the district is very generally occupied by farms. The height to which the rock masses once rose above the present surface is reasonably estimated as at least one mile; it may have been two or three. The wearing down of these ancient mountains to the rolling plain of to-day has required an enormously long period of time.

It often happens that the plain surface of a worn-down mountain range is here and there surmounted by rounded

hills or low mountains, 1000 or more feet high, composed of the most resistant rocks of the whole region. These hills are the last remnants of the mountains that once towered over the surface of to-day. Several hills of this kind are scattered over the Piedmont plain of Virginia, one being shown in Figure 99. Such remnant hills and

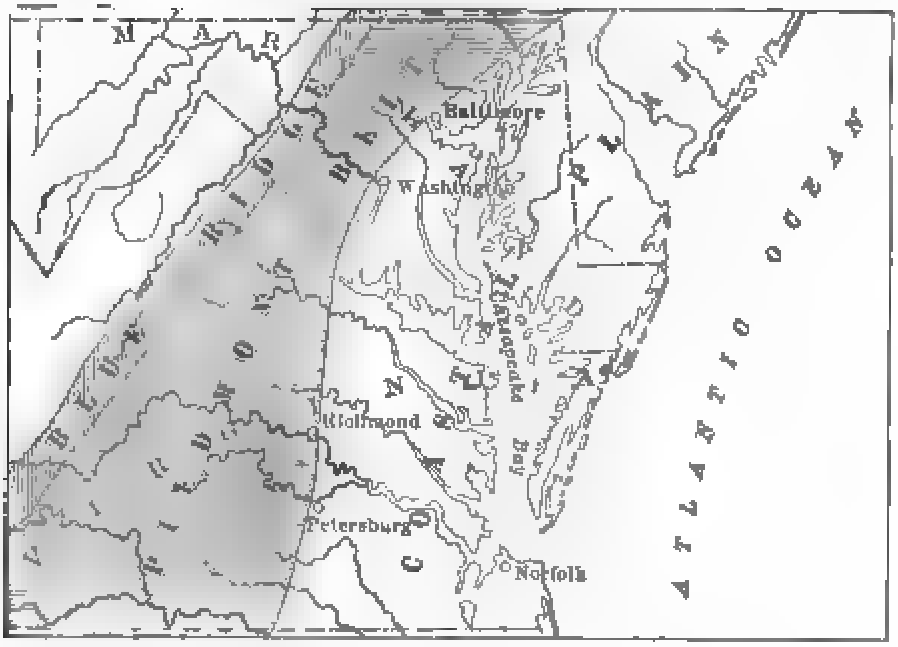

FIG. 100. Map of the Piedmont Belt, Virginia

mountains are often called *monadnocks*, after an excellent example of their class in southwestern New Hampshire.

It is generally the case that old-mountain lowlands are now uplifted above the position in which they stood when worn down, so that they form plateaulike uplands. Their streams are thus revived into a new period of activity and at once proceed to trench and dissect the upland.

The Piedmont belt of Virginia now stands several hundred feet above baselevel. It is cut across by a number of active streams that flow in rocky, steep-sided valleys

from 100 to 300 feet below the upland plain. It must therefore be supposed that this region has been somewhat uplifted since its ancient mountains were worn down. It is in the valley sides that the tilted rock structures in the foundations of the ancient mountains are best seen.

Southern New Hampshire and Vermont, central and western Massachusetts, and all of Connecticut include many uplands, above which occasional hills and low mountains

FIG. 101. The Upland of New England, with Mt. Monadnock in the Distance and a Valley in the Foreground

rise, and below which numerous open valleys are worn. When an observer stands on the uplands the sky line is seen to be comparatively even. If the valleys were in imagination filled up again to the level of the uplands, the worn-down peneplain of the ancient mountains of New England would be restored.

The peneplain does not now stand so low as when it was worn down. It has been uplifted into a slanting position, so that it slowly rises from sea level at Long Island sound to a height of from 1400 to 1600 feet on the northern boundary of central and western Massachusetts. The

valleys have been carved because the old lowland has been lifted up. They are shallow near the coast, but deep (800 to 1000 feet) in the interior, where the upland is higher above baselevel. They are comparatively narrow where the rocks are so resistant that they weather slowly, but wide open where the rocks are weaker. The chief of the wider valleys is that of the Connecticut river, a

FIG. 102. Valley of the Deerfield in the New England Upland

broad lowland excavated along a belt of relatively weak sandstones.

The uplands have a scattered farming population, here and there gathered in small villages. The larger valleys contain many villages and cities, and guide the chief roads and railroads. Here is gathered the more active manufacturing and commercial population of New England.

124. Old Mountain Ridges. — The Allegheny mountains of Pennsylvania and Virginia consist of a number of nearly parallel ridges with remarkably even crest lines, here and there cut down by the notches or water gaps of streams and rivers. The strata of these mountain belts are strongly

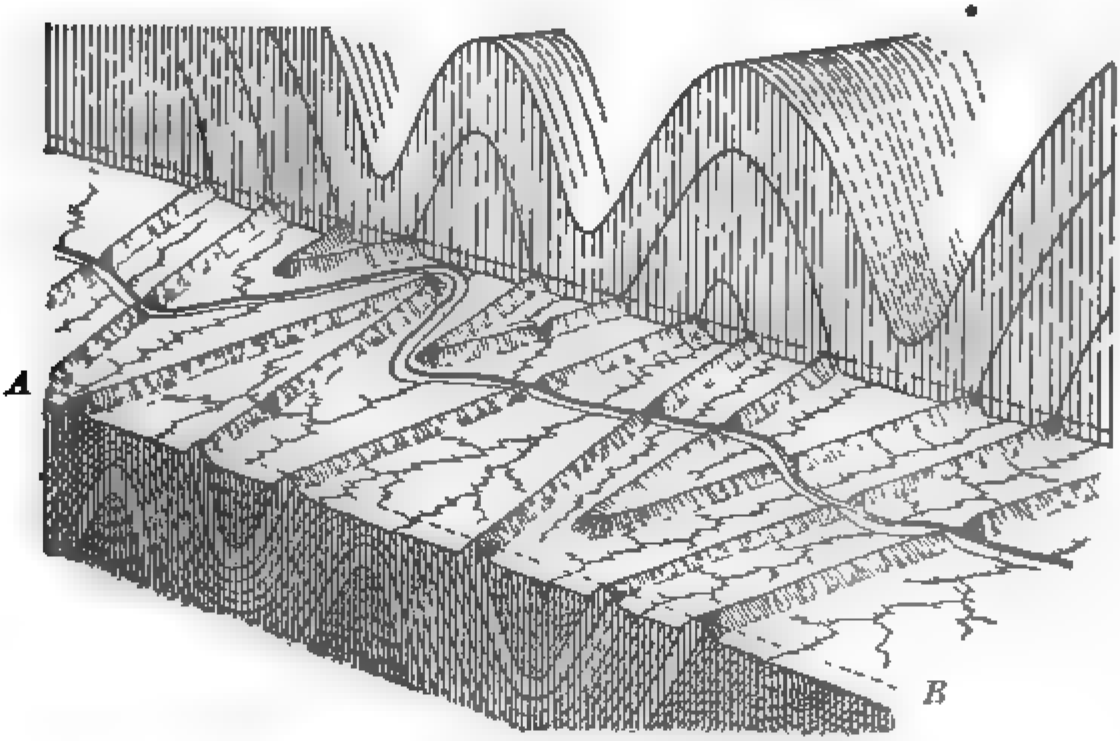

FIG. 103. Diagram of the Allegheny Mountains, Pennsylvania

folded, so that, if unworn, they would rise in great arches, as in the background of Figure 103.

But it is now so long since the strata were pressed into folds that they have been worn down to a low peneplain at the level of the dotted line *AB*, in the foreground of Figure 103. The peneplain thus formed has been uplifted one or two thousand feet; the weaker strata have been again worn down, forming open valleys and leaving the harder strata standing in relief, as

PLATE IX. A Water Gap in the Allegheny Mountains, Maryland

even-crested ridges. The waste from the open valleys has been washed out through the notches that have been slowly cut down where the streams flowed across the harder strata.

Plate IX shows one of these ridges in Maryland, with a notch cut through it by a branch of the Potomac river. How many notches are shown in Figure 103?

125. Embayed Mountains.—If a mountain range near a continental border is lowered, it will be partly covered by

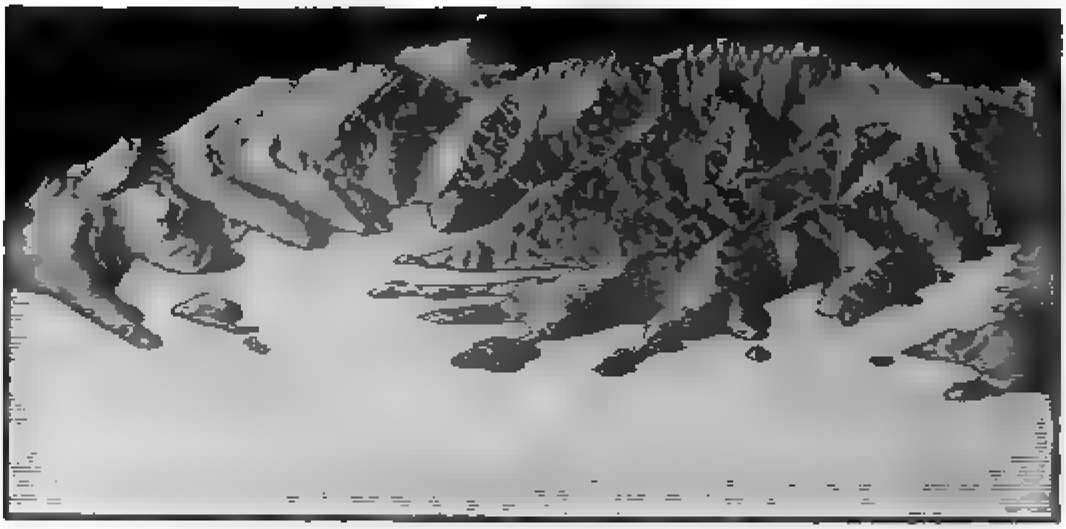

FIG. 104. Model of Embayed Mountains

Compare Figures 60, 62, and 104. Compare Figures 71 and 104.

the sea. The effect thus produced will be similar to that observed in the half-drowned coastal plain already described. The valley floors and mountain flanks will be submerged to a greater or less depth, and many long bays will enter between outstretching promontories and islands, as in Figure 104. Islands of this kind are called continental because of their close relation to the neighboring land.

The coast of British Columbia and southern Alaska is bordered by high mountains, into whose valleys the sea now enters in long and deep passages, called *fiords*. Lateral ridges, separated from the mainland by water channels or sounds, stand forth as islands. A navigable "inner passage," well protected from the rough water of the open ocean, is thus provided for steam vessels. The steep mountain sides, descending rapidly beneath the sea, generally offer no flat ground for settlement; but most of the fiords now contain delta plains where streams enter their heads; here villages find convenient sites.

The coast of Maine, part of the dissected upland in the old mountain region of New England, has been partly submerged, so that it is entered by many long arms of the sea and fringed by many islands. Excellent harbors are thus provided, and many of the people living near the coast are sailors and fishermen.

QUESTIONS

SEC. 108. What is a mountain range? a mountain system? How do mountains differ from plateaus? What is the action of mountain-making forces? State a theory of their origin. How do streams affect mountain form? To what two processes is mountain form due?

109. Describe an example of block mountains. Where are good examples of this class found? How has the form of these mountains been produced? How do the forms of several blocks vary? What can be said of the age of these mountains? Why may it be believed that these mountains are still growing? Describe the drainage of these mountains. Consider the climate of the region. Describe the places of settlement.

110. Describe the dissected ranges of Nevada. Compare them with the block mountains of Oregon. Are the Nevada ranges still growing? Compare the climate of the ranges of Nevada and of Oregon. Describe the streams of the Nevada ranges. Where are settlements found among these ranges?

111. Where are the Jura mountains? What is their structure? How have these mountains been produced? How is their structure related to their form? What changes have been produced by erosion? Describe the drainage of these mountains. Compare the side ravines and the crossing gorges. State the location of villages and roads.

112, 113. Name some lofty mountain ranges. Upon what two processes does the form of these mountains depend? Compare the importance of land sculpture in these ranges and in the block mountains of Oregon. Of what do the lofty peaks and ridges consist? What becomes of the waste from them? What is the origin of the deep valleys? Compare the domes and the horns of the Alps. Compare the Selkirk range of Canada and the Rocky mountains of Colorado.

114. Compare plains and mountains as to variation of temperature; of rainfall; as to conditions of life. Why are the sources of large rivers often found in mountains?

115. How do mountains act as barriers? Compare the two slopes of the equatorial Andes as to climate and vegetation. What influence is exerted on climate by the Sierra Nevada and the Rocky mountains? What is the chinook wind? the foehn? How have the Himalayas acted as barriers between nations? How do mountain ranges serve as national boundaries? Give examples. Explain the importance of passes. How are roads and railroads built over mountains? Give an illustration of mountains as an obstacle to travel.

116, 117. What are avalanches? How are they caused? How do they move? How are villages and roads protected from them? Describe an ice fall in the Alps. What is a landslide? Describe the landslide of Airolo in the Alps; of the upper Ganges in the Himalayas. What disaster followed the latter landslide? How were its dangers lessened?

118. Describe the movement of rock waste in mountains. How is the form of the waste fragments changed? What is an alluvial fan? How is it formed? How does the form of alluvial fans vary? How do fans affect the course of a river in front of them? How does the course of a torrent vary on its fan? Describe Two-Ocean creek. To what dangers are villages and roads on fans exposed? Describe an example from Switzerland. Describe and explain a waste-filled valley. Describe and explain a terraced valley.

119. How are valleys widened? What sort of valleys are widened most easily? Describe crosswise valleys. Compare lengthwise and crosswise valleys as to occupation.

120. What is an earthquake? How are earthquakes related to mountains? How fast do earthquake tremors travel? How much movement may they cause? Where are the shocks felt most violently? How far may they be felt? How often do earthquakes occur in the Alps? Describe the great earthquake of India, 1897. What effect was produced by an earthquake in Japan in 1891?

121. Compare the people of mountains with those of the neighboring lowlands.

122. Describe subdued mountains as to height, form, rock waste, earthquakes, landslides. Describe an example of this class. What effects have these mountains on their inhabitants?

123. What is meant by worn-down mountains? What is a peneplain? Describe an example in Virginia. What is a monadnock? Describe and explain the valleys of the Virginia Piedmont belt. Describe and explain the uplands and valleys of southern New England. How do they influence the distribution of population?

124. Describe the Allegheny ridges as to form; as to origin; as to drainage. What is a water gap?

125. Describe the appearance of embayed mountains. What is their origin? What is a continental island? Describe the coast of southern Alaska; the coast of Maine.

CHAPTER VII

VOLCANOES

126. Volcanic Eruptions. — Most of the processes of nature go on without violence. The usual movements of the winds and currents, the flow and ebb of the tides, the rise and fall of the lands, the weathering and washing of rock waste are so placid that we gain confidence in the earth as a safe home to live in. But sometimes natural processes of a more violent behavior are witnessed. Hurricanes and tornadoes bring destructive winds and torrential rains, flashes of lightning and peals of thunder. Landslides rush down mountain sides, overwhelming the valleys below. Now and then the rocky crust beneath us quivers and trembles in earthquakes. Great waves occasionally roll in from the sea and sweep over low coastal lands. Here and there volcanoes burst forth with terrible commotion. Nature then seems frightful and destructive. Those who are overtaken by such disasters struggle against them, hopefully awaiting the return of the more peaceful conditions under which their habits of life have been formed, for man could not survive if he were always battling against the wilder forces of nature.

Of all natural catastrophes, the explosive eruption of a great volcano is the most terrible. The air resounds

with its roaring. The sky is darkened and the sun is hidden by clouds of dust blown from the crater. The sea is burdened with floating ashes. Glowing streams of molten rock, or lava, flow down the flanks of the volcano, driving away everything that can take flight before them. Even the earth around trembles as the gases and lavas burst out from their deep sources. No wonder that ignorant races of men have imagined struggling giants to be imprisoned under active volcanoes, nor that even the most learned are baffled when trying to account for these terrific displays of natural forces.

But violent as a volcanic eruption may be, it weakens and in time ceases. The sky clears, the sun shines again, and nature once more goes on with her more quiet tasks. As the years pass by and a soil is formed on the weathered lavas, plants clothe their surface and man comes to dwell on the flanks of the volcanic mountain. The eruption is forgotten; fields and villages occupy the volcanic slopes; little remains to tell of the commotion of former times.

127. Young Volcanoes. — Volcanoes are formed by the ascent of molten lava through fractures or passages leading from unknown depths beneath the earth's crust to its surface, on the land or on the sea floor. Although the lava is very hot, it is not burning or flaming. A volcano should never be described as a burning mountain.

It is believed by many that the ascent of molten lava from its deep source is chiefly caused by pressures similar to those which cause movements in the earth's crust in

mountain building. As the lava nears the surface and meets water in greater or less quantities, explosions of steam and other heated gases take a violent part in the eruptions.

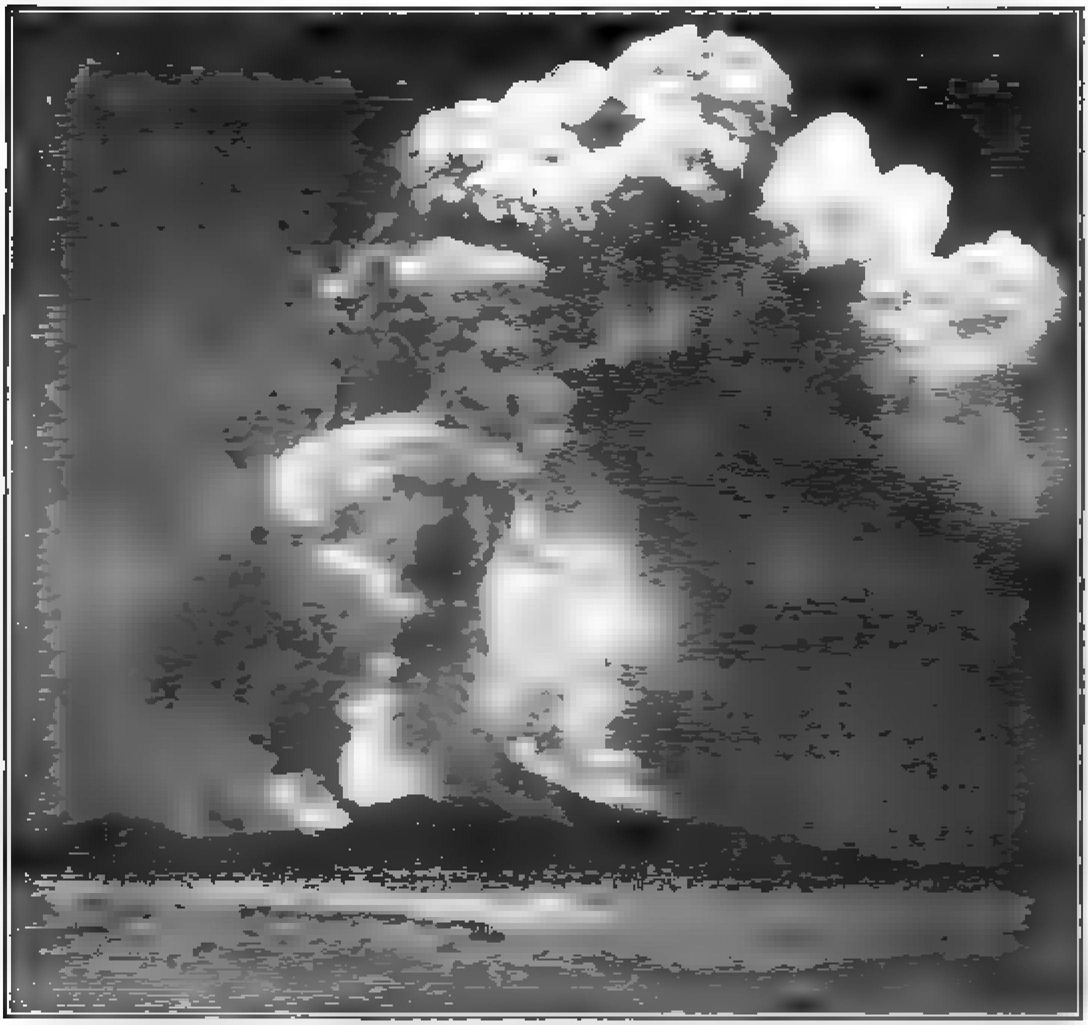

Fig. 105. Vesuvius in Eruption

The early growth of a volcano has occasionally been observed. The outburst is preceded and accompanied by earthquakes, which indicate the breaking of an upward passage through the underground rocks, before hot lavas make their appearance at the surface. When the eruption is

accompanied by gaseous explosions much of the lava is blown into fragments, of which the smaller are called ashes or cinders. The larger blocks and the coarser ashes accumulate in a conical heap, or volcano, frequently having remarkable regularity of form, a cup-shaped hollow or crater being kept open at the top over the vent by the outbursting gases. The finer ashes or dust may fall far away. When the eruption is less violent the lava runs forth more quietly in a stream or flow, following the slopes of the ground. Explosive and quiet eruptions may alternate in irregular succession, and after many eruptions the volcano may become a lofty mountain, one or two miles high.

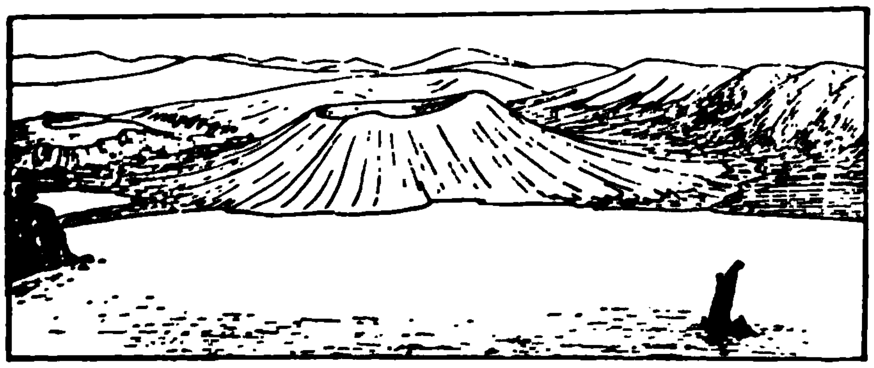

FIG. 106. Monte Nuovo

Monte Nuovo (new mountain) is a small volcano that was formed on the north side of the Gulf of Naples in Italy in 1538. Earthquakes occurred thereabouts for two years before the eruption, when in a week's time a cone was built up 440 feet high, half a mile in diameter at the base, and with a crater over 400 feet deep. Masses of lava "as large as an ox" were shot into the air by the bursting of great bubbles of gas or steam that ascended through the lava in the vent. Finer ashes fell over the country for several miles around. The people of the neighboring villages fled in terror from their homes.

A greater eruption took place in Mexico in 1759, when the volcano Jorullo (pron. *Ho-rul-yo*) was built on the central plateau, burying fertile fields of sugar cane and indigo. The outburst was preceded by earthquakes; the eruption continued half a year, building six cones and pouring out extensive lava flows. The highest cone, Jorullo, rose 700 feet above the plateau. The flows retained a perceptible heat for over twenty years.

Many examples might be given of marine eruptions. In 1867 a shoal was discovered among the Tonga islands of the Pacific (lat. 20° 20′ S., long. 175° 20′ W.), the surrounding sea floor being about 1000 fathoms deep. In 1877 smoke was seen ascending from the sea surface over the shoal. In 1885 an island had been formed two miles long and 200 feet high. At this time a terrific eruption was in progress, and the shocks of the explosions were felt on neighboring islands. As the island consisted chiefly of ashes, it has since been rapidly eroded by the waves and will soon disappear, unless new eruptions occur.

Most volcanoes have not been observed in their early growth, yet, even if not now in eruption, so perfectly do they correspond in form and structure with such examples as Monte Nuovo and Jorullo that no doubt can remain as to their origin.

In northern California there is a cinder cone of remarkably perfect form. Its barren slopes of loose ashes rise 640 feet to the rim that incloses a crater 240 feet deep. A stream of lava has issued from near the base of the cone, flooding a neighboring valley with a lava field a mile wide and nearly three miles long. The surface of the field is

so covered with unweathered angular blocks of lava as to be almost impassable. The edge of the field is a steep and ragged slope 100 feet high. It obstructs a stream from the south, which forms Snag lake, so called from the dead trees still standing in it. On all sides the surface of the country is covered with a layer of volcanic ashes and dust, six or more feet deep near the cone, thinner and finer farther away, yet recognizable at a distance of eight miles.

FIG. 107. Cinder Cone and Lava Flow, California

From the size of trees growing on the ashes it is estimated that the cinder cone was built about 200 years ago. The lava flow is younger, but none of the Indians or early settlers thereabouts (1845) observed its eruption.

128. Great Volcanoes. — Many large volcanoes, whose first eruption must have occurred many thousands of years ago, are still active. After long periods of more or less complete rest they burst forth again for a short time, blowing out showers of ashes, building their cones to a height of 10,000 feet or more, and adding new lava streams to their flanks, so as to gain a diameter of ten or twenty miles or more at the base. The melted lava often breaks

forth from the mountain side and flows down to gentler slopes on the flanks and out upon the surrounding country; thus the cone as a whole comes to have a rudely bedded structure of ashy and dense lavas.

It sometimes happens that the upper part of a volcano is destroyed by a violent eruption or broken in by underground disturbance, forming a greatly enlarged crater, or caldera. Volcanoes of this form are sometimes called ring mountains.

Deception island, in the South Shetland group, beyond Cape Horn, is the high rim of a caldera, breached on one side by a narrow gap, which gives entrance to a quiet circular bay. Layers of ice are to be seen between beds of ashes and lava on the caldera walls.

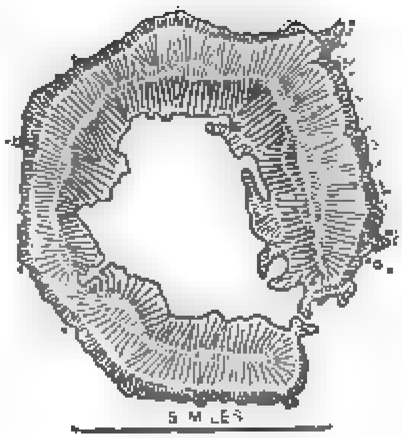

FIG. 108. Deception Island, a Volcanic Caldera (plan and section)

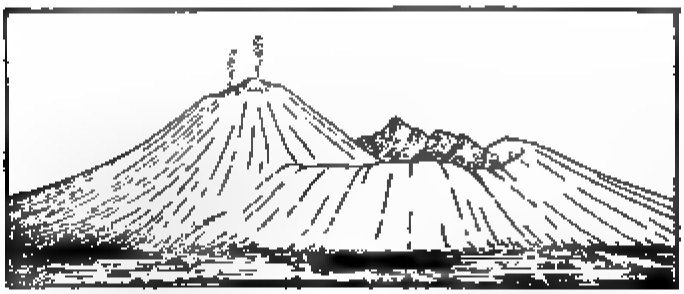

FIG. 109. The Cone of Vesuvius in the Caldera of Monte Somma (looking north)

The cone of Vesuvius has been built in a large caldera of more ancient origin. The cone buries one side of the caldera rim, the other side being known as Monte Somma.

Draw a map of Vesuvius and Monte Somma, like the map of Deception island in Figure 108.

Mt. Mazama, a superb ring mountain in Oregon, contains a beautiful lake in its huge caldera. This volcano must have been once several thousand feet higher than it is now, before its upper part was engulfed in the formation of the caldera.

Figures 110 and 115 are maps of Mts. Mazama and Shasta, in which the mountain form is indicated by lines that curve around the slopes at definite heights, every line following a level course, and every pair

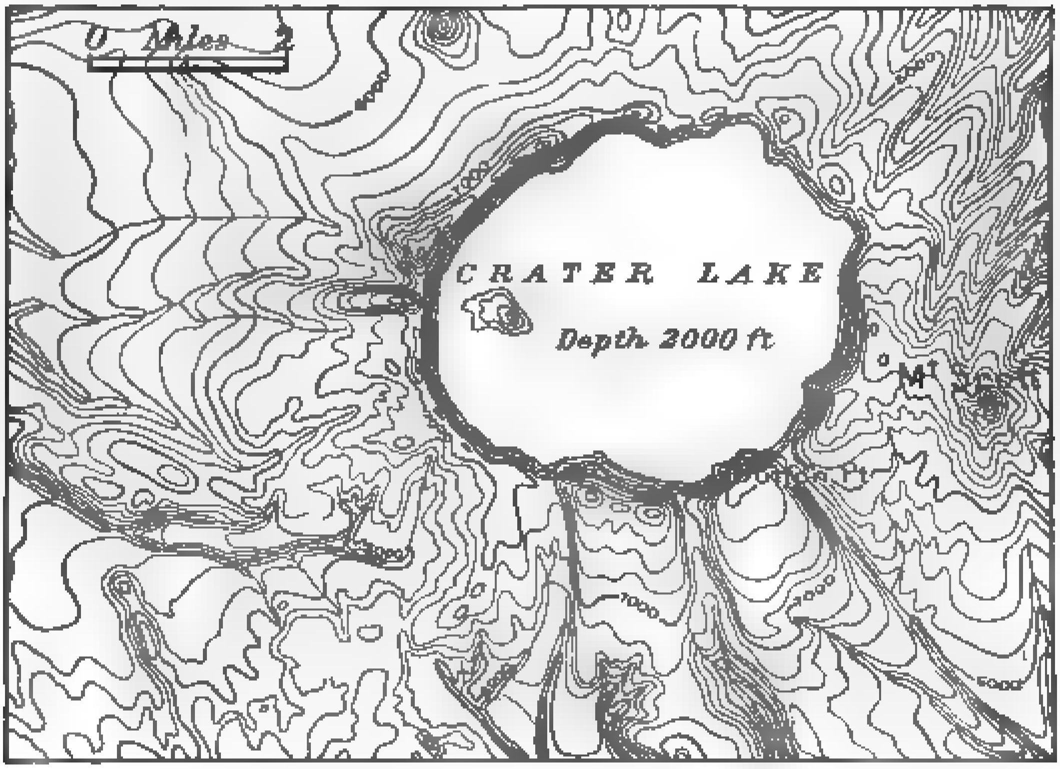

Fig. 110. Contour Map of Crater Lake in Mt. Mazama, Oregon

of lines differing in height by a fixed amount. Lines of this kind are called contour lines, and the maps are contour maps. Where the lines are open spaced, the slopes are relatively gentle; where the lines are close together, the slopes are steep. Compare the inward and outward slopes of the ring of Mt. Mazama; compare the upper and lower slopes of Mt. Shasta. Determine from Figure 110 the diameter of the caldera, and the average height of its rim above sea level and above the lake surface.

A rough classification of volcanoes groups them as active, when they are frequently in eruption; dormant (sleeping), when now at rest, though giving signs in hot springs and sulphurous vapors that activity may be begun again; and extinct, when they give no sign of activity. It is not possible to make certain distinction between the last two classes; great eruptions have taken place in volcanoes after all signs of activity had ceased.

Showers of ashes as they chance to fall may bury villages, fields, and forests. The disturbance in the atmosphere during a violent eruption often causes rainfall. The floods thus caused may be increased by the water from melted snow on the upper slopes of a lofty cone, and occasionally by hot water thrown out from the crater itself. The floods gather the fresh-fallen dust and ashes, producing muddy torrents that overwhelm the lower lands.

At the eruption of Conseguina, Central America, in 1835, ashes destroyed trees and dwellings twenty-five miles south of the volcano; thousands of cattle and innumerable wild animals and birds were killed. Lava blocks in fragments five or more feet in diameter are strewn for ten or fifteen miles around the great cone of Cotopaxi, Ecuador.

A tremendous eruption of Galung-gung, a forested volcano in a populous part of Java, took place in 1822; torrents of hot water, mud, and ashes rushed down the valleys, flooding the rivers and drowning a great number of men and animals; for twenty-four miles not a trace of numerous villages and plantations was left.

The first recorded eruption of Vesuvius, A.D. 79, darkened the sky with its clouds. The ancient city of Pompeii

was buried in ashes and about 2000 persons (estimated at one fifteenth of the population) were killed. Herculaneum, near by, was overwhelmed with torrents of ashy mud. After being long forgotten and overgrown by modern

Fig. 111. Excavations in Herculaneum

villages, parts of these cities have been laid bare by recent excavations, affording many illustrations of ancient architecture and of ancient modes of living. The walls in the foreground of Figure 111 are the ruins of houses in ancient Herculaneum. They were buried to the level *LL*.

129. Earthquakes in Volcanic Districts.—The shocks of a violent eruption may shatter the volcano, breaking its sides.

The earthquakes thus caused are felt for many miles around the volcano. The exploding gases produce thundering sounds, sometimes audible for hundreds of miles.

In the remarkable explosion of the volcanic island of Krakatoa, already referred to (page 27), half the island was destroyed, leaving water more than 1000 feet deep where high land had stood before. The air was shaken so vigorously by the explosion that windows were broken a hundred miles away. Huge sea waves rolled away from the exploded island, causing great destruction on neighboring coasts. Pumice, or light spongy lava, formed a floating layer on the sea surface, obstructing the course of vessels. The dust blown out of the volcano darkened the air for hundreds of miles around. As the dust was spread far and wide by the upper atmospheric currents, it increased the brilliancy of sunset and sunrise colors. The famous "red sunsets" thus produced were visible in all parts of the world before the end of 1883; then, as the dust settled, their brilliancy gradually decreased.

Besides the earthquakes directly produced by the explosive eruptions of volcanoes, it is probable that many other earthquakes in volcanic districts are the result of disturbances within the crust of the earth not directly connected with volcanic action. The numerous earthquakes of Japan and Italy sometimes accompany eruptions, but are more frequently independent of all visible eruptive action.

Great destruction is caused by earthquakes in regions that are frequently shaken. In the thickly populated districts of southern Italy many thousands of lives have been lost in the violent earthquakes of the last three centuries.

130. Distribution of Volcanoes. — Volcanoes generally occur near the seacoast or on the sea floor, but a considerable number of cones and flows are known far in continental interiors. Volcanoes are more numerous on the lands bordering the Pacific ocean and the mediterranean seas than on the coasts of the Atlantic, but many volcanic islands are known in the Atlantic, as well as in the Pacific and Indian oceans. It is estimated that over 300 volcanoes are now active, about 100 of these standing on the continents. All high islands of small area, far from the continents, and many such islands near the continents are of volcanic origin.

Extinct volcanoes are sometimes found far inland. Cinder cones and barren lavas are known on the plateaus of Arizona, 300 miles from the ocean; in Colorado, 800 or more miles inland; in Tibet, 500 or more miles inland. Several active volcanoes in Mexico, Central America, and elsewhere are so far from the coast that direct connection with sea water should not be regarded (as it has been) necessary to eruptions.

Active volcanoes in the interior of continents are rare, but a large one is known in central Africa, north of Lake Tanganyika, 700 miles from the Indian ocean.

Islands formed by the growth of volcanoes in mid ocean are often bordered by wave-cut cliffs, so that it is almost impossible to find a landing place on their shores. Being of rugged form and nearly inaccessible, as well as distant from the continents, they are all the more lonesome.

A remarkable instance of the effect of isolation on the occupants of a remote volcanic island is seen in the language of the people of Iceland. Icelandic, Norwegian, Swedish,

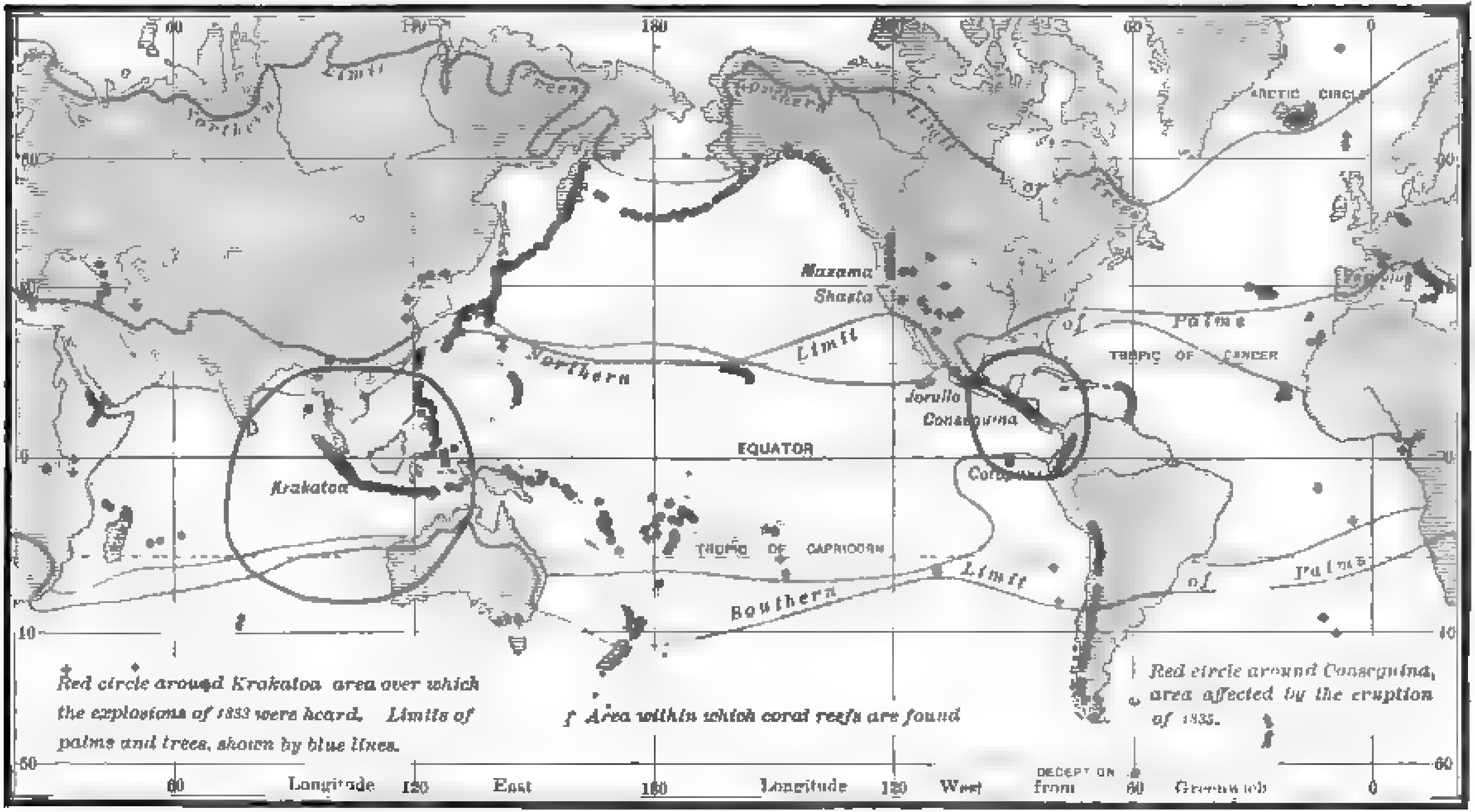

FIG. 112. Distribution of Volcanoes and Coral Islands. Active and recently active volcanoes, red dots. Long extinct volcanoes, red crosses

and Danish were all one language a thousand years ago; but while the isolated Icelandic has preserved its ancient form with slight change, the languages of the continental countries have been much modified; that of Denmark especially having been affected by the neighborhood of Germany.

131. Lava Flows. — Great flows of lava sometimes run beyond the base of the volcano in which they break forth. Their surface is comparatively smooth if it remains

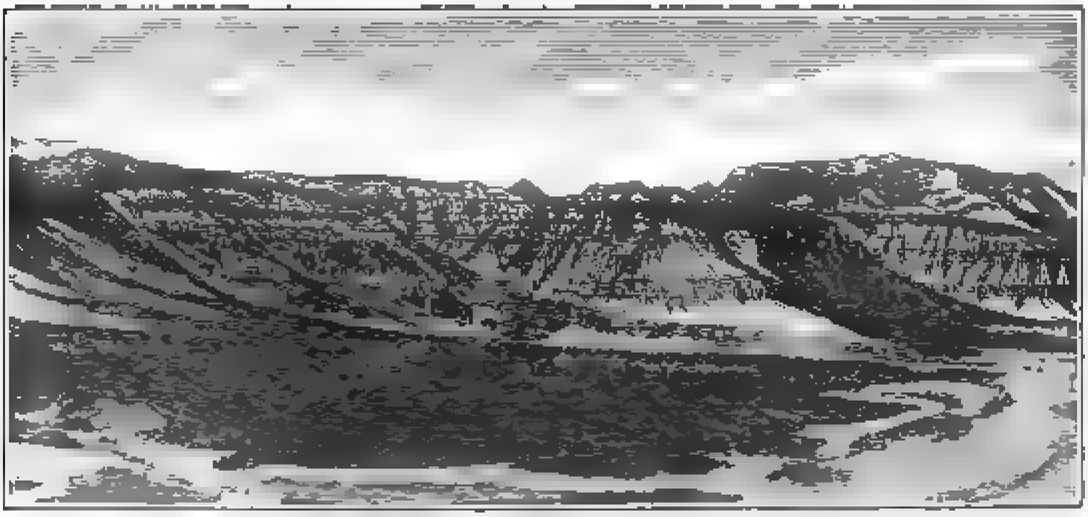

FIG. 113. Lava Flows on the Plateaus of Arizona

unbroken after first cooling, but extremely ragged and angular if the first crust is repeatedly broken by continued movement. The edge of a ragged flow may form a bluff 100 feet or more in height. On one of the plateaus of Arizona near the Colorado canyon stands a throng of volcanic cones, from which broad streams of lava descend the bordering cliffs in black cascades and form barren lava floods on a lower plateau near by.

In 1783 a great flood of lava rose from a deep fissure in Iceland, the lava issuing tranquilly for the most part, flowing away in vast sheets on each side, and advancing in streams far along the lower valleys. Hundreds of small cones were built over the fissure, which was twenty miles long. In the course of ages successive lava floods of this kind have built up broad uplands in the plateau of Iceland, the loose slaggy cones of earlier eruptions being gradually buried under later sheets.

Two lava streams of the eruption of 1783 in Iceland flowed down valleys forty-five and fifty miles from their source, gaining a depth of several hundred feet where the valleys were narrow, and spreading out in lakelike plains where the valleys were open. The water of side streams was dammed and rose in lakes. Twenty villages were destroyed by the floods of lava or water; 9000 persons (about one seventh of the island's population) and a great number of cattle perished, not only at the time of the eruption, but afterward during a famine caused by the burial of the pastures and by the desertion of the coast by fish.

The form assumed by successive lava flows in building a plateau is sometimes imitated on a cold winter night when trickling streams of water, supplied by daytime thawing, are frozen as they advance. If the water is artificially colored, successive flows are made plainly visible.

Lava floods thousands of square miles in area have been poured forth in Idaho, Oregon, and Washington, where they form an extensive plateau in a broad depression among the surrounding mountains.

Between the Columbia and Snake rivers, in eastern Washington, the plain surface of the lava flood meets the inclosing mountains just as the sea meets a half-drowned mountain range. The lava forms level bays between the ridges; the ridges stand forth like promontories; outstanding peaks rise like islands over the plain. A rugged mountainous basin has thus been converted into a plateau. Part of the lava plain has been uplifted in domelike form to a greater height than the rest and is now deeply dissected by the canyons of Snake river and its branches. This part is called the Blue mountains, *B*, Figure 114.

FIG. 114. The Lava Plateau of Idaho, Oregon, and Washington

132. Dissected Volcanoes.—Torrential streams running down the slope of volcanic cones carve ravines on their flanks. Many ravines are formed during the periods of rest in the growth of great volcanoes, only to be filled again by later eruptions of lavas and ashes. After eruptions cease the ravines deepen more and more, leaving sharp ridges between them, and at last dissecting the cone so deeply as to leave little appearance of its original shape.

Mt. Shasta, in northern California, is furrowed on all sides by gigantic ravines, but its conical form is still well preserved, Figures 115, 116. Many meadows about its

base mark the sites of lakes formed by lava-flow barriers but now filled and drained. The best agricultural land in the region is of this origin.

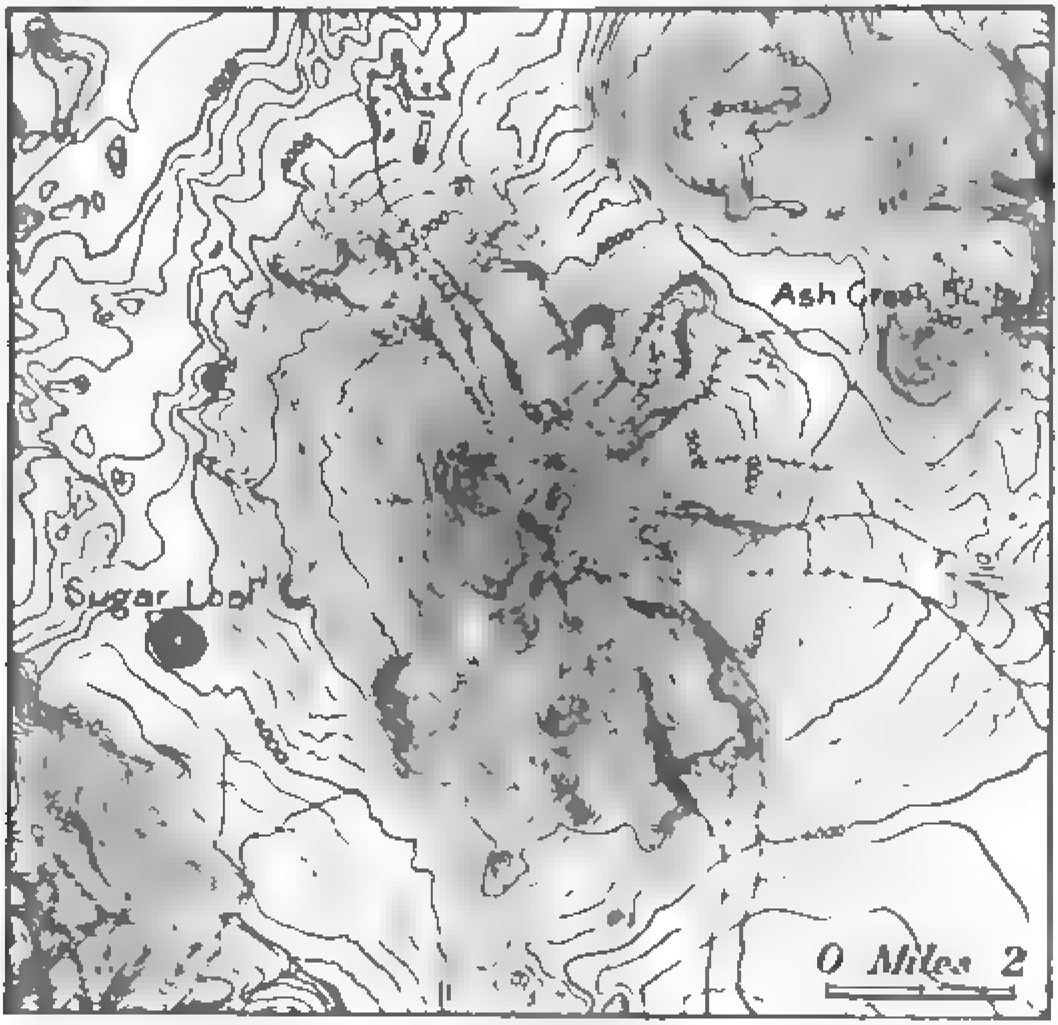

FIG. 115. Contour Map of Mount Shasta, California

A number of extinct and more or less dilapidated volcanic cones surmount the plateaus of Arizona and New Mexico, Mts. San Francisco and Taylor being among the best examples.

Before the summit of Mt. Mazama was destroyed by engulfment its height was probably about equal to that

of Mt. Shasta to-day. Ravines like those of Shasta had been worn down the slopes of Mazama; their lower courses are still seen on the outer slopes of the ring mountain, but their upper courses are lost.

Many great volcanoes in various stages of activity and dissection are found in the Andes along the western side of South America.

FIG. 116. Mount Shasta

133. Geographical Changes caused by Volcanoes. — The construction of large volcanoes by successive eruptions sometimes causes curious changes in the course of rivers, whose valleys are more or less blockaded by the new-built cones.

A remarkable example of this kind is found in Central America, where the growth of a range of volcanoes has transformed a bay that once opened to the Pacific into a lake, known as Lake Nicaragua. The volcanoes formed so

effective a barrier that the lake surface is now 105 feet above sea level and its outlet flows across what used to be the continental divide and discharges into the Caribbean sea. Since the outlet took this course it has eroded a

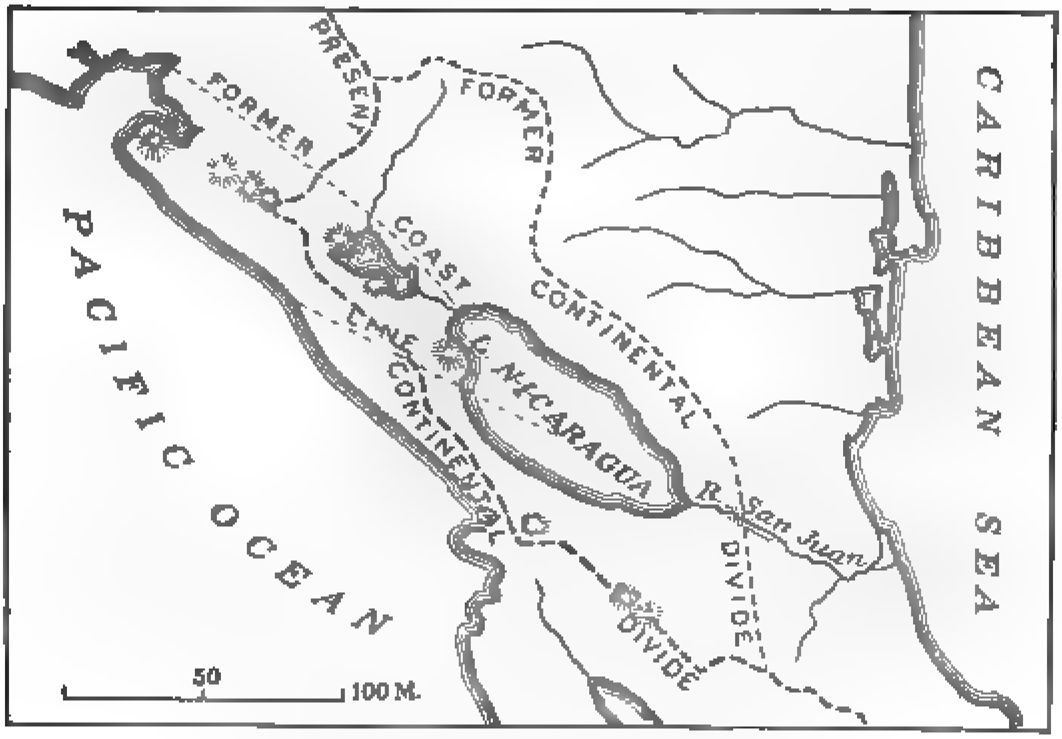

Fig. 117. Map of the Lake Nicaragua District

deep gorge across the divide, and the level of the lake is now lower than when the eastward overflow first took place. This lake would form part of the proposed interoceanic canal route across Nicaragua.

Draw a map, based on Figure 117, to show the general outline of the land before the volcanic range was built. The original outline of the bay now closed by the volcanoes and their lava flows is shown by a dotted line. Describe the changes caused by the building of the volcanic range.

QUESTIONS

SEC. 126. Give examples of the quiet processes of nature; of the violent processes. Describe the explosive eruption of a volcano.

127. How are volcanoes formed? What is the most probable cause of the ascent of lava in volcanoes? What is the effect of steam? Describe the early growth of a volcano. Give an example from near Naples; from Mexico; in the Pacific. Describe the cinder cone in California. How did its lava flow affect a neighboring stream? Why is this volcano thought to be of recent origin?

128. How are great volcanoes formed? What size do they attain? What is a caldera? Describe Deception island; Vesuvius and Monte Somma; Mt. Mazama and its caldera. How may volcanoes be classified? What effects may be produced by showers of ashes? by floods? How may these floods be caused? Describe some incidents of the eruption of Conseguina, 1835; of Cotopaxi; of Galunggung. What can you tell of Pompeii and Herculaneum?

129. Why are earthquakes often associated with volcanoes? Describe the explosion of Krakatoa.

130. How are volcanoes distributed? Compare the Atlantic and Pacific in this respect. How many active volcanoes are known? How many of these are on the continents? Where are volcanic islands found? What forms have they? Where are extinct volcanoes often found? Where is an active volcano found far inland? Give an instance of the effects of living on a remote volcanic island.

131. Describe the surface form of lava flows. Describe the lava cascades near the Colorado canyon; the eruption and lava flood of 1783 in Iceland; the lava floods of Idaho.

132. Describe a dissected volcano. Name some examples of this class. Compare Mts. Shasta and Mazama.

133. What geographical changes may be produced by volcanoes? Describe an example of such changes in Nicaragua.

CHAPTER VIII

RIVERS AND VALLEYS

134. Underground Water. — The water supplied by rain and snow is disposed of in part by evaporating from the surface, in part by running down the slopes of the land to the streams, and in part by sinking underground. The latter part is called underground water, or simply ground water.

The proportions of these several parts vary under different conditions. The greater part of a light and long-continued rain may pass underground, especially if falling on a plain. A very heavy rain, or "cloud-burst," falling on strong slopes is largely disposed of by direct run-off, causing sudden floods.

Rain, falling on a surface having a deep soil well covered with vegetation (grass, bushes, or forest), will for the most part soak into the ground. On arid plains a great part of a light rain may dry off from the barren surface of the ground, but a heavy rain will run off in a flood.

Loosely consolidated strata and deep rock waste take in much ground water. Firm rocks, such as granites, allow but little water to enter beneath the weathered waste on their surface. When the ground is frozen little water can enter it; hence rivers rise in floods when deep snow is rapidly melted by a heavy rain.

Underground water is essential to the growth of plants, whose roots must reach moist earth. Where grass and trees cover the surface, much ground water taken in by their roots is discharged into the air by evaporation from their leaves.

135. Caverns. — Most rocks are not soluble in water. Limestone is exceptional in this respect; it may be slowly dissolved, especially by ground water, which gathers certain acids from decomposing vegetation as it soaks down through the soil. Caverns in limestone districts are the result of this solvent action of underground waters. The Mammoth cave of Kentucky and the Luray cavern of Virginia are famous examples of their class. Streams gathering on the surface descend to underground passages by hollows, known as *sink holes* or *swallow holes*. After flowing underground for some distance such streams may issue in enlarged and turbid currents from the mouths of caverns.

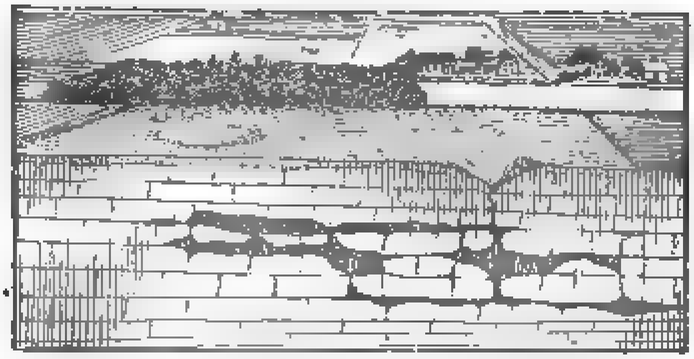

FIG. 118. Diagram of Cavern and Sink Hole

Where sink holes and cavern drainage prevail so much water enters the ground that surface streams are comparatively rare. When the sink holes or the underground passages become obstructed ponds and lakes are formed in the surface basins.

Several species of animals dwelling in the complete darkness of caverns are blind, but their senses of hearing and touch are highly developed.

As the cavern enlarges, its roof may fall in more or less completely. The beautiful Natural bridge of Virginia is the remnant of a cavern roof.

136. Springs. — Very little ground water remains permanently beneath the land surface. Sooner or later, after descending to less or greater depths, it returns to the surface at a lower level than where it entered, coming out in the form of springs and joining the run-off of streams.

The movement of ground water is comparatively slow while percolating among the particles of rock waste or through the pores and crevices of rocks. Where a large part of the rainfall enters the ground, the volume of the streams fed by springs is less variable than where the rainfall is mostly discharged by direct run-off during and shortly after a storm.

It is for this reason that the springs and streams of a forested region usually have a comparatively constant flow; but this rule does not apply in regions of strong relief, such as the dissected plateau of West Virginia. When forests are cut down, the direct run-off of the rainfall is increased; then the springs are likely to run dry and the streams will vary greatly in volume between flood and drought.

Ground water slowly moves from hills and slopes, descending to lower levels and accumulating beneath the lower ground. It may, therefore, be generally found near the surface in valleys, where the soil is usually damp. At

the base of a slope the ground water may issue in a spring, *S*, Figure 119, supplying a small brook. Innumerable small springs occur unnoticed in the banks of streams.

Ground water stands close to the land surface in marshes, swamps, and bogs, rising or falling somewhat with changes of weather and season.

In regions of sufficient rainfall and moderate relief the ground water may be reached at almost any point except on hilltops by sinking wells to a depth of from ten to forty

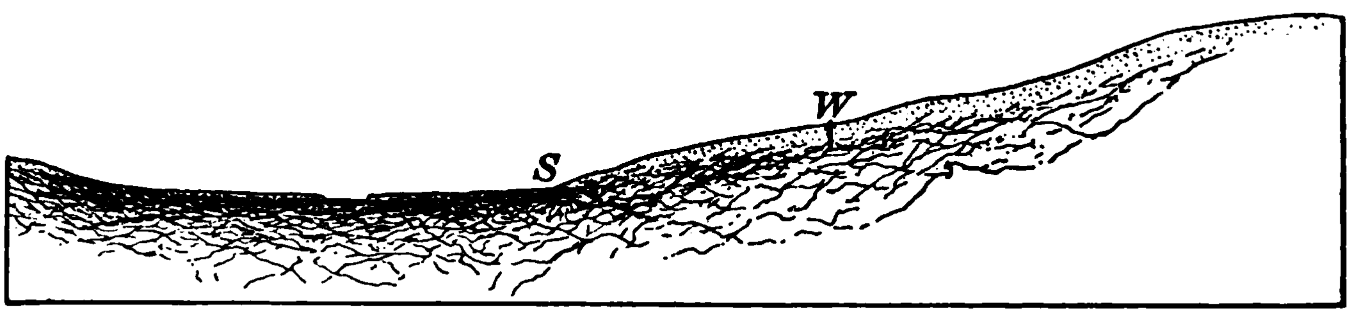

FIG. 119. Section showing Ground Water in Rock Crevices beneath a Valley

feet. The bottom of the well should be a few feet deeper than the level at which the trickling stream of ground water enters it, so as to accumulate water in sufficient volume to supply ordinary domestic needs.

Ground water and spring water carry very little rock waste (unless in solution) and are generally clear and pure. For this reason wells and springs generally afford a better water supply than the surface streams that receive the wash of fields and meadows.

In coastal regions ground water may flow forth as springs directly into the sea, either on a sloping beach near low-tide level, or at the bottom offshore; here they sometimes have a current so abundant as to supply a column of fresh water that ascends through the heavier salt water to the surface.

137. Artesian Wells. — In many coastal and interior plains a large part of the rainfall enters the more sandy layers and follows their gentle slope deep underground, between other layers that are less open to the passage of water. If a deep well is sunk to the water-bearing stratum, the water may rise and flow out of the surface like a fountain. Wells of this kind are called *Artesian*, from Artois, a district in France where they were first bored.

It is essential that the water-bearing stratum should receive its rainfall at a higher level than that of the top of the well by which it is tapped, as shown in Figure 120.

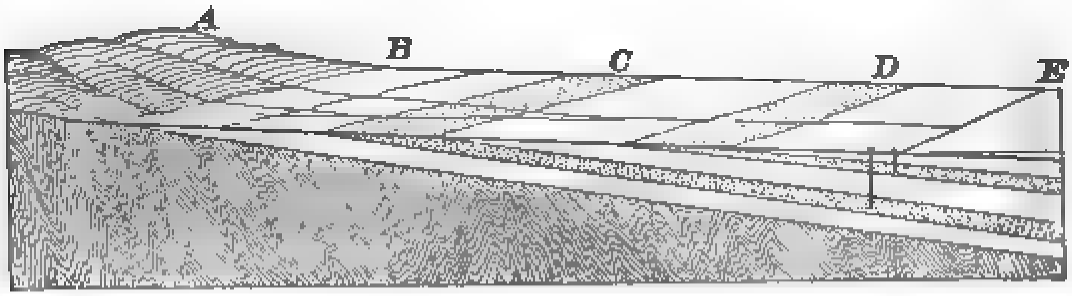

FIG. 120. Diagram of a Coastal Plain with Artesian Wells

In what part of the plain does the stratum tapped by the deeper well reach the surface?

Charleston, Galveston, and many other coastal cities receive much water supply from artesian wells. In eastern Maryland deep wells pierce strata that reach the surface and receive rainfall west of Chesapeake bay; the strata lead the water beneath the nearly water-tight layers that floor the bay, and it is still fresh when rising in the wells. Southern Wisconsin and eastern Iowa have many artesian wells, supplied by water-bearing strata that slope gently away from the older land of northern Wisconsin.

138. Hot and Mineral Springs. — Ground water sometimes descends deep beneath the surface with a slow supply from a large area. While deep underground the water acquires a high temperature and stands under a heavy pressure. It is shown by experiment that hot water under pressure has increased power of dissolving certain minerals. Hence the slowly percolating water takes into solution what it can dissolve of the more soluble minerals discovered on its way, such as calcite (the mineral base of limestone), salt, and certain compounds of magnesia, iron, etc. If the water then rises rather rapidly along a rock fracture, it will appear at the surface in springs, bearing an unusual amount of mineral substances in solution and often having a high temperature. Such springs are frequently of medicinal value.

Springs of this kind are associated with disturbed rock structures such as occur in mountainous districts. Saratoga Springs, N.Y., White Sulphur Springs, W.Va., Vichy in central France, and Karlsbad in Bohemia are examples of settlements determined chiefly or wholly by the value of their medicinal waters. Many other mineral springs occur in the Appalachian and Rocky mountains.

139. Geysers. — In certain volcanic regions the temperature of the underground water may rise to or above the boiling point. Steam then issues with the water, often in a more or less explosive manner, and such steaming and spouting springs are called geysers. The geysers of Iceland have long been famous; those of the Yellowstone Park are now the most celebrated in the world.

The jet of steaming water and spray may rise for several minutes to a height of a hundred feet, with a loud roaring noise. Then all remains quiet till the next eruption, usually a number of hours later. Mineral substances that were dissolved in small quantity by the hot water underground are partly deposited near the geyser's vent as the water cools or evaporates, and thus a mound or terrace of mineral deposits is gradually formed. The terraces around the hot springs of the Yellowstone Park are of great beauty.

FIG. 121. A Geyser

The intermittent action of many geysers suggests that a certain period of time (an hour or more) is necessary to warm the new supply of water that enters the crevice of discharge after a previous supply has been blown out by steam. Water under pressure must be heated above the ordinary boiling point (212° F.) before it will change to steam. Hence in the deeper part of the crevice the temperature of the boiling point is higher than at the surface. When the deeper water reaches its boiling point a great part of it is quickly converted into steam, which blows the rest of the water out of the vent.

140. Mud Volcanoes. — Certain hot springs bring a considerable amount of fine rock waste to the surface with their steaming water. The waste is then deposited as a muddy sediment around the opening of the spring, where it forms a mound with a hollow or crater in the center. Although seldom over a few score feet in height, the resemblance of these mounds to true volcanoes has given them the name of mud volcanoes. A number of mud volcanoes occur in the Yellowstone Park, where some of them are only a few feet high. Some of the largest known, with heights up to 400 feet, are near the lower course of the river Indus in northwest India.

141. River Systems and their Parts. — A river is a stream of water bearing the rainfall and the waste of the land from higher to lower ground and, as a rule, to the sea. A trunk stream and all the branches that join it constitute a river system.

Stream is a general term, with little relation to size. Rill, rivulet, brook, and creek apply to streams of small or moderate size. River is generally applied to the trunk or to the larger branches of a river system.

A river flows in a channel that is somewhat lower than the adjoining land surface. The floor of the channel is the river bed; the sides of the channel are the river banks. The coarser part of the waste borne by the river is swept along the bed; the finer part may be carried in the stream.

The land from which a river gathers its water and its load of rock waste is called its basin. The crest line, or "height of

land," between the basins of neighboring streams or rivers, or between the valleys of river branches, is called a divide.

FIG. 122. A Dividing Ridge in the Mountains of Northwest England

Trace the divide shown in Figure 122. Note that a divide may be much higher at one point than at another. Follow some of the simple and branching divides shown in Figures 86 and 104.

The land slopes in opposite directions on the two sides of a divide. When rain falls on the adjoining slopes it will be shed into different streams; hence a divide is sometimes called a watershed or water parting. Certain crest lines in the Rocky mountains separate the basins of rivers which discharge into the Atlantic and the Pacific oceans; these crests constitute the "continental divide." Name some of the rivers that are thus divided.

On smooth plains and uplands there is no well-marked height of land or ridge separating the headwaters and side streams of neighboring rivers. Such surfaces may be described as having an undivided or imperfectly divided drainage. Undivided drainage areas are often found on young plains and plateaus. Compare the foreground and background of Figure 62 in this respect.

When a plain or plateau or mountain region is well dissected numerous sharply defined subdivides are developed between the smaller rivers and their branches, as on the Allegheny plateau. River and stream basins in vigorous mountains are sharply divided by the crest lines of the lofty ridges between the deeply eroded valleys. A worn-down region may have indistinct divides, as on the even uplands of the Piedmont belt of Virginia, Figure 99.

Nearly all these features of river systems may be illustrated in a small way by the temporary streams on a road surface just after a fall of rain. Many interesting studies may be made of the small stream basins, divides, branches and channels, and of the manner in which the streams bear waste from higher to lower ground.

142. Floods and Droughts.—The volume of a river varies with the change in the amount of rainfall over its basin. During and shortly after a rain (or a thaw of snow) the surface run-off is most active; all the rivulets are running with water and waste to the creeks, and the creeks run to the rivers. The volume of all the streams is increased at such a time, and their current is quickened. The water is then turbid with the waste that has been washed into the streams by the rivulets on the valley sides and lifted from the stream beds by the strengthened currents. As the stream volume increases, the water may rise above the banks of the channel and overflow the low ground or flood plain on either side. There some of the fine river-borne waste, or silt, will be deposited as the current slackens.

When the rain stops and the surface run-off lessens and ceases the flooded streams are drained down the valleys toward the sea; their volume decreases and their surface sinks to a more ordinary level. Then the streams must depend on ground water supplied by springs at innumerable points in the stream beds. Less waste is washed into the streams at this time, and their current may become nearly or quite clear.

During a drought of several weeks or months the streams drain away much of the ground water. Then the discharge of the springs is weakened, and the streams are reduced to smaller volume. They may shrink so much as to be unable to cover all the bed of their channel, especially in the head-water branches. The streams may entirely disappear for a time, but even if lost at the surface, ground water may generally be found slowly creeping through the sand and gravel of the channel bed a few feet below the surface.

In regions of plentiful rainfall, like the eastern United States, the rivers may be much reduced during droughts, but they do not entirely disappear. In the drier climate of many of the Western States the streams habitually disappear and leave their channels dry during the long intervals between rain storms.

143. The Work of Rivers. — Frequent reference has already been made to the work of rivers in sculpturing the lands. This important subject may now be considered more carefully. The higher a river lies above baselevel, the deeper may its valley in time be worn. The steeper the channel, the faster the river flows and the more and the coarser rock waste it may sweep and carry downstream. The greater the volume of a river on a given slope, the less it is retarded by friction on the bed and banks, and the faster it flows. Hence a river in flood flows faster than at time of low water, and the flooded current transports a greatly increased load of rock waste. Indeed, it is chiefly in time of flood that the work of a river is performed.

The deepening of a valley by the erosion of rock in the river channel is accomplished chiefly by the rasping of the rock surface with the innumerable fragments and particles of rock waste that are swept over it. The more resistant the rock, the slower it will be worn down. The particles thus worn from the rock surface make part of the load of waste borne away by the river.

As the valley bottom is worn deeper and deeper below the surrounding country, the valley sides are attacked by

the weather, and much waste washes and creeps down from them into the river, thus widening the valley, decreasing the steepness of its side slopes, and adding to the load of waste borne away by the stream. It is in this sense that it is said that "rivers erode their valleys." Another portion of the river load is received from the headwaters and side streams, which in turn receive it chiefly from the wash of waste down the side slopes of their valleys at times of rain or thaw.

The load of waste thus gathered is not swept along in a continuous movement to the sea; it stops many times on the way, being laid down on the bed or sides of the channel when the water is low, forming bars and banks; it is swept forward again a greater or less distance at time of flood.

Rivers that are beginning their work of erosion and transportation in sculpturing a newly uplifted land may be called young. When they have worked so long that all the land slopes in their basin have been worn down low, so as to form a surface of faint relief — a peneplain — at a small altitude above sea level, the rivers may be called old. Between youth and old age, when the rivers are actively working in well-carved valleys, sweeping along the waste received from the hills or mountains that form the valley sides, they may be called middle-aged or mature.

144. Young Rivers. — The examples of land forms described in earlier chapters have shown that when a region is first raised from the sea, or when a former land surface is uplifted, tilted, or folded, the streams as

a rule follow the lead of the land slopes, uniting here and there to form rivers of larger and larger size.

Young rivers thus newly established proceed to cut down their channels where the slope is steep enough to give them an active current; the waste that they gather is washed along, rasping down the ledges in the river bed; but where the slope is very faint, or where rivers enter a basin holding a lake, they lay down their load of waste and build up the land surface.

While rivers are still young their course is often marked by rapids and falls, not yet eroded away, and by lakes not yet filled up with sediments or drained away by the deepening of their outlet by the outflowing stream. The current of such rivers is irregular, being very fast at rapids and falls and almost wanting in lakes. As the river grows older both the falls and the lakes disappear and the current becomes more uniform.

The drainage of the Laurentian highlands of Canada north of the St. Lawrence river bears every mark of youth. Lakes are very numerous and of irregular form. They often have several outlets, no one stream having cut down enough faster than the others to secure all the discharge. The streams are frequently interrupted by rapids or falls on rock ledges, in which channels are as yet cut only to moderate depth. The rivers frequently split into two or more channels, which reunite after wandering in independent courses for ten or twenty miles across country.

These highlands are a rugged, forested, and thinly populated wilderness without roads. All travel is by canoes

along the water courses, and the canoes have to be carried past every rapid and fall. The birch tree, from whose bark portable canoes are made, is here as appropriate to the needs of the inhabitants as the camel is to the dwellers in arid deserts.

The St. Lawrence system, with its many lakes, falls, and rapids, is a remarkable example of very young or

Fig. 123. Niagara Falls

undeveloped drainage. The outlet of Lake Superior is by a river interrupted by rapids, called the Sault Sainte Marie (Soo St. Mary). The outlet of Lake Erie is Niagara, with its renowned cataract and rapids. The outlet of Lake Ontario is the St. Lawrence, with numerous rapids. The lakes favor navigation, but the rapids and falls obstruct it. Canals and locks have now been

constructed, by which the rapids and falls are passed. Name the great lakes of the St. Lawrence system.

The region of the great African lakes bears many marks of youthful drainage. The lake basins here indicate a breaking or warping of the earth's crust, like that in southern Oregon. The inclosing plateaus are bordered by ragged cliffs, where fractures have taken place. The Nile, flowing north from Lake Victoria Nyanza, and the Shiré, flowing south from Lake Nyassa, are young rivers of powerful current, descending over falls and rapids, and are very busy in the work of deepening their valleys and draining the lakes.

By long-continued action the path of a river will in time be everywhere worn down or built up to such a slope that the current will be just strong enough to carry the load of waste that it receives. Such a river may be described as passing from youth to maturity.

145. Lakes may be generally taken to indicate a youthful drainage system, as in the examples just given. In time they will be destroyed, partly by filling with the waste that is brought by the inflowing streams, partly by the deepening of the outlet valley. Lakes should therefore be regarded as only temporary features in the long life of the river system to which they belong. The rivers may remain long after the lakes disappear.

The depressions between the tilted lava blocks of southern Oregon hold lakes because enough time has not yet passed to enable the streams to fill and drain their basins. Lava flows obstruct streams and for a time hold back lakes. Lakes of other kinds will be described later.

As the current of a river decreases on entering a lake, the stream-borne waste settles: thus deltas are formed at the inlets and the lake bottom is strewn with the finest waste or silt.

Lake Geneva in Switzerland receives the Rhone at its east end; the river is turbid with the waste that it has received from Alpine glaciers and torrents. A delta twenty miles long has been built into the lake. It has grown a mile forward since Roman times, nearly 2000 years ago. The lake bottom is a plain of fine silt. When even the finest silt has settled, the lake water becomes very clear, and the Rhone at the outlet is wonderfully transparent.

Lakes act as regulators of the discharge of their outflowing rivers; for the level of the lake changes little, whether the inflowing streams are flooded or low, and hence the outlet river has a relatively constant volume.

The Ohio without lakes and the St. Lawrence with five great lakes are strongly contrasted in respect to floods. The latter has no great floods, because even a heavy rain raises the surface of the lakes gradually and only by a small amount; hence the outflowing river cannot be greatly increased in volume. The rains of the upper Ohio basin, a hilly district, are not detained in lakes, but quickly flow down the hillsides to the streams. Floods in the Ohio valley may rise fifty or sixty feet in a few days, spreading to ten or twenty times the usual width of the river and causing great damage to villages and cities on the valley floor.

146. Falls and Rapids. — When a river begins to wear its valley it rushes down any descending slope that occurs on its course. Here a gorge is cut as the rocks are rasped away by the gravel and sand in the rapid current. Niagara, when first taking its present course, fell over the north-facing bluff of the upland

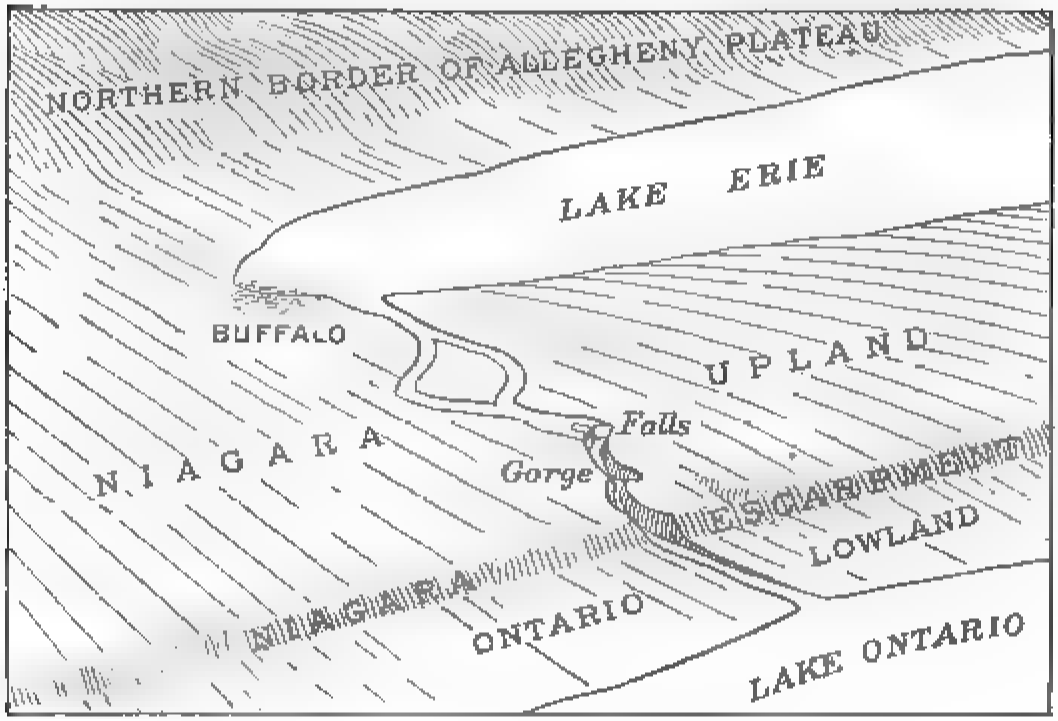

FIG. 124. Diagram of Niagara River between Lakes Erie and Ontario

that separates the basin of Lake Erie from that of Lake Ontario; since then the river has cut back a gorge about seven miles long from the edge of the upland; the falls now plunge into the head of the gorge. The larger or Canadian fall is now retreating three or more feet a year at its middle.

The falls of the Yellowstone river occur at the head of a deep canyon cut by the river in the process of deepening

its course through a lava plateau. As the falls are worn back the gorge is lengthened.

While a stream is engaged in deepening its valley it often flows from a harder to a softer rock structure. It will deepen the valley much more quickly in the latter than in the former, and a rapid or fall will be formed on

FIG. 125. Falls of the Yellowstone River

the abrupt slope between the two. Falls and rapids of this kind are numerous, especially in dissected plateaus and mountains.

It has long been the custom to build mills near falls, so that part or all of the descending water may be used to turn water wheels and thus to drive the machinery of the mills. Villages have often grown up around the mills and factories thus located. As the work of the mills increases it has frequently been necessary to add steam

power to water power; at the same time the village may grow to be a large city. In recent years it has been found possible to transform the power of falling water into an electric current, which may be carried many miles through

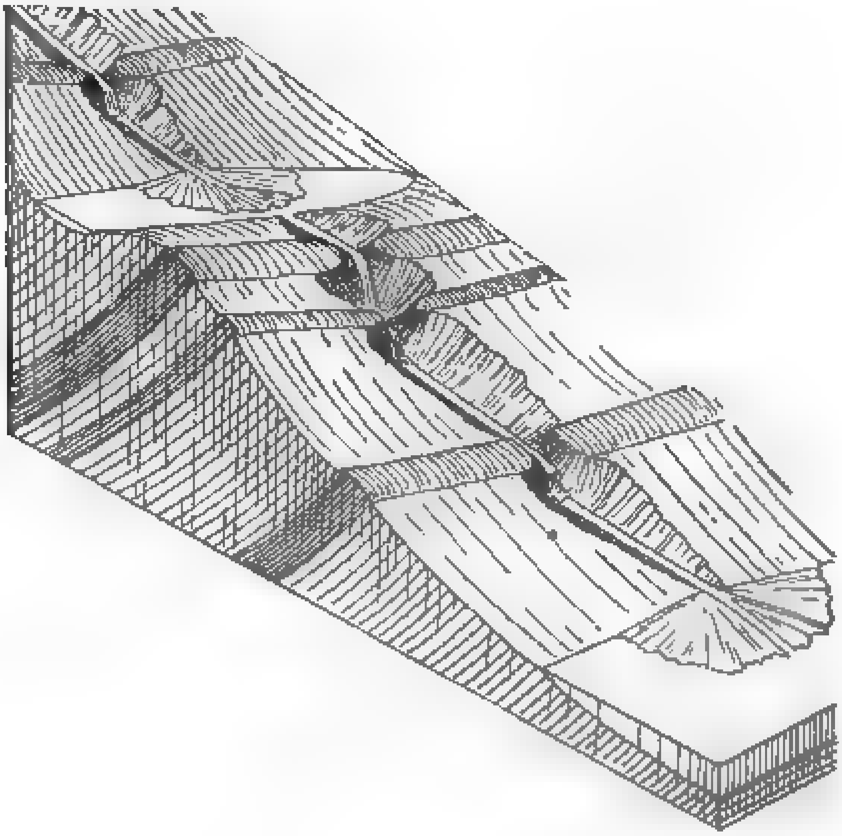

FIG. 126. Diagram of Torrent, with Falls and Reaches

How many falls are shown in Figure 126? Draw a profile along the river course and compare its slope at and between the falls. Why are some of the stretches between the falls longer than others? Where are the gorges deepest?

wires and then set to work to drive machinery, to run cars, or to furnish electric light. Waterfalls in thinly populated mountains may thus in time come to be used to supply electric power to cities on the neighboring plains.

147. Graded Rivers. — A river cannot wear down its course to a level, for there must be some slope down which the current, bearing its load of rock waste, may flow toward its mouth. While the slope is strong and the current is very swift the stream is called a torrent. The waste is then swept along so actively that bare rock is commonly seen in the stream bed. Torrential streams are usually clear, because they quickly sweep away the fine particles that they receive from time to time, leaving coarse cobbles and bowlders lying on their rocky channels. Such streams are still young.

As time passes and the channel is eroded deeper and deeper it will be worn down more nearly level, closer and closer to baselevel. But it must always preserve a slope sufficient to give the water a velocity that will enable it to wash forward the load of waste received from the headwaters and side streams, though without either deepening or building up the bed of the channel significantly. When such a slope is attained the river is said to be graded. It has reached maturity.

The current of a graded river is usually deliberate instead of torrential. Its bed and banks consist, for the most part, of deposits of rock waste; firm ledges are seldom seen along its course. The water is usually made somewhat turbid or muddy by the presence of fine waste, with which it is plentifully supplied by its tributaries and by the wash from its bed and banks.

In valleys among high mountains, where an abundant supply of coarse waste is washed down from the steep valley sides, graded streams must have a slope strong

enough to give them an active current; otherwise their coarse and abundant load could not be washed forward. In lowlands where only fine-textured waste of the land is slowly washed into the streams, graded rivers have a very gentle descent.

Water moves so easily that large rivers assume very faint slopes; the lower Mississippi has a descent of only two or three inches to the mile, yet it bears along a vast amount of rock waste, — 6700 million cubic feet of suspended silt, 750 million of silt dragged along the bottom, and 1400 million of minerals in solution every year.

148. Reaches and Rapids. — A longer time is required to wear a valley down to grade where the rocks are resistant than where they are weak. If a river crosses a succession of weak and strong rocks, as in Figure 126, the graded condition will be first attained on the weak rocks, and each reach of the river on the weak rocks will be graded with reference to the sill of hard rocks next downstream or with reference to the lake or sea into which the river may flow. The sills of hard rocks then serve as local baselevels with respect to which the stretch or reach next upstream is graded.

Many rivers come in this way to be divided into long smooth reaches and short plunging rapids or falls. Most of the rivers of New England and of eastern Canada are in this condition.

When a river system has been undisturbed for a long period of time, even the resistant rocks are worn down. Few falls then remain to interrupt the steady flow of the

river current, and its graded reaches become longer and longer. The side streams, following the example of the master stream, wear down the side valleys so as to join the main valley at even grade. It is in this well-established condition that many large rivers of the world are found.

When a graded condition is reached in even the smaller branches of a river system the slope will be steepest in the headwater streams and least near the river mouth; thus the profile of a well-developed river is a curve of decreasing slope from head to mouth.

149. The Development of Valleys.—While a young river is deepening its valley, the valley sides are steep and the valley bottom is no wider than the river channel, as in Figure 127. At such a time the valley floor offers no attraction to settlement, as it affords no level ground for roads near the river; roads built in such a valley must perch on the side slope. If the valley is deep, like the Colorado canyon, it may act as a barrier between the uplands on either side.

Floods have little room to spread in a steep-sided valley; hence they rise rapidly on the valley walls, even thirty feet or more in a day or two. Thus confined in the valley, the flood flows rapidly and sweeps away all obstacles, gradually subsiding as its supply of water lessens.

It is for this reason difficult to maintain road bridges across the streams of the Allegheny plateau, Figure 79; the great expense of building strong and high bridges cannot be borne by the scattered population. The streams are therefore commonly crossed by fording. At time of high water travel is interrupted.

The continued action of the river, wearing first on one bank and then on the other, gradually widens the valley floor. At the same time the sides of the valley are

FIG. 127. Valley of Yakima River, Washington

worn back to gentler slopes, and the valley floor becomes more accessible.

At this stage of development the valley is much more available for human uses than when young, narrow, and

steep-walled. Villages may be built and fields may be cultivated on the valley floor. Roads may follow it on each side of the river. Instead of being a trenchlike barrier between two highlands, the valley has now become a well-graded pathway for settlement and for trade between the upper and lower parts of the river system to which it

FIG. 128. The Mohawk Valley

belongs. The Mohawk valley in eastern New York, Figure 128, is a good example of this kind. Another is shown in Plate X.

The behavior of rivers during the advance in the development of their valleys must now be considered in greater detail.

150. The Development of Flood Plains. — In a winding stream the fastest current is displaced from the middle of the channel toward the outer bank. Such a stream

PLATE X. Dinant on the Meuse, Belgium

therefore tends to cut more on the outer bank than on the inner bank at every turn; hence as it cuts down it also cuts sideways.

When grade is reached the valley walls will be slanting, but they will be steepest on the outer side of every bend, where the stream has undercut the valley wall, as in Figure 129. The valley walls will therefore be equally steep on the two sides only where the valley is straight. At each turn sloping spurs descend opposite abrupt cliffs, and the belt of country occupied by the turns of the river is broader than at first.

Draw a map of the district shown in Figure 130 *a*, following the style of Figure 129, and show where the river is undercutting the cliffs. The river is supposed to be flowing toward the front of the diagram in Figure 130.

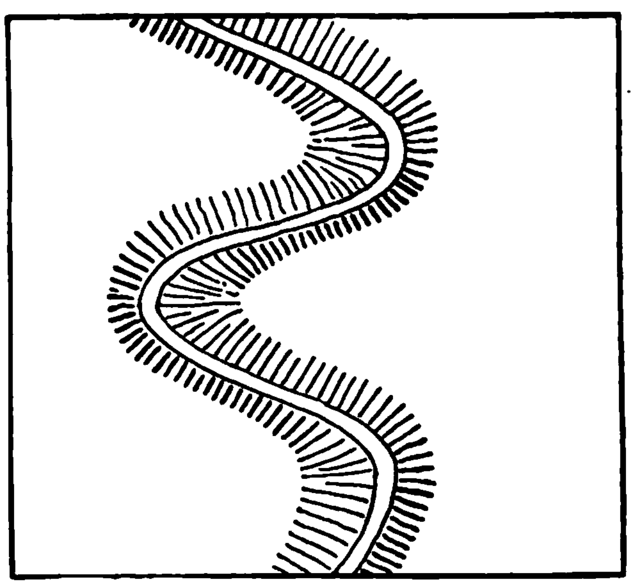

Fig. 129. Outline Map of a Young Valley

When a river has worn down its valley to a gentle slope it still wears on the outer bank of every turn, because the strong current runs there; thus the valley floor is broadened. At the same time the turns tend to become smooth curves of regular form.

As the outer bank of a curving channel is slowly cut away, the inner bank, where the current runs slower, is gradually filled up nearly to high-water level with rock waste from farther upstream. A curved strip of flat valley floor is thus developed on the inner side of each curve, as in

Plate XI. The Braided Channels of the River Var in the Western Alps

Which side (up-valley or down-valley) of the middle spur in Figure 130 *c* has been worn away? Draw a map representing Figure 130 *d*.

Describe the form of the upland in the diagrams of Figure 130. Compare the form and breadth of the flood plain in the different diagrams. Compare the slopes of the valley sides. Compare the forms of the upland spurs that enter the curves of the valley.

When a river overflows, the greatest amount of silt is laid down on the flood plain near the river channel. Thus in time the plain comes to have a gentle slope away from the river on either side, as well as down the valley.

If a stream has a large load of coarse rock waste, its graded flood plain must be relatively steep (a descent of from five to twenty feet or more in a mile). In this case the stream does not turn far aside from a direct course along the flood plain to form serpentine curves; but it is constantly embarrassed by the formation of bars and islands of gravel and sand, splitting its current into a braided network of channels.

The Platte is a river of this kind. It gathers much waste from the weaker rocks of the Great plains and therefore requires a rather strong slope for its graded valley floor. Many rivers flowing from the Alps to the lower lands have gravel bars and islands between their braided channels, as in Plate XI.

151. River Meanders. — If the waste borne by a river is of very fine texture, the flood plain will have a very gentle grade. Then the river easily turns aside from a direct course on its broadened flood plain, and in this

way (whatever its original path) develops a system of serpentine curves, as in Figure 130 *d*, *e*. Curves of this kind are called ***meanders***, after the Meander, a winding river of Asia Minor. How many turns does the river make in Figure 131?

The size of the meanders increases with the volume of the stream. A meadow brook may swing around curves

FIG. 131. A Meandering River, Vale of Kashmir, India

measuring only forty or fifty feet across. The curves of the lower Mississippi are from three to six miles across. The flatter the flood plain, the greater is the meander turning. The Koros, Figure 132, on the Plain of Hungary, has its meanders remarkably developed.

Meanders are slowly changed, for the river wears away the outer bank of each curve because the current runs fastest there; the opposite side of the channel is filled

in with waste where the current is slow. The Mississippi below Cairo has in the course of ages shifted its course, now eastward, now westward, and has thus opened a flood plain from twenty to sixty miles wide, that is, five or six times wider than its meander belt. Similar changes may be seen on a small scale in a meadow brook.

In the fine silt of a broad and flat flood plain a large river changes its course easily and rapidly; it takes material from the outer bank, where its current is strong, and deposits it farther downstream on the inner bank, where the current is weaker.

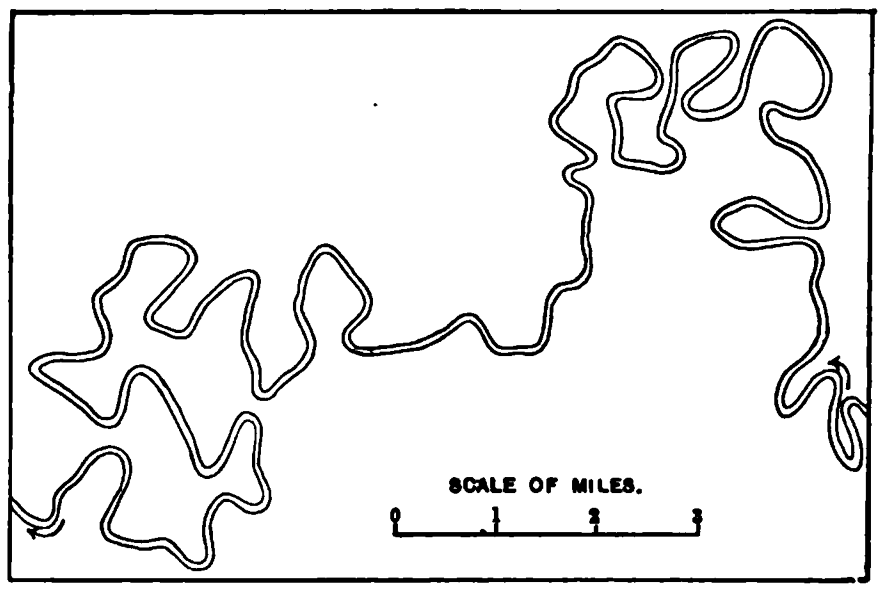

Fig. 132. A Meandering River on the Plain of Hungary

The necks of the flood-plain spurs between adjoining meanders are often gradually narrowed and cut through by the river, the meander around the spur being then deserted for a shorter and more direct course, called a cut-off. Where are cut-offs likely to occur in Figure 132?

Large rivers, like the Mississippi, exhibit all stages of this process. An abandoned meander is occupied by nearly stagnant water, more or less completely separated from the new and shorter channel by deposits of silt in the ends of its arms; in time it becomes an *oxbow lake.*

Draw an outline map to show the probable path of the Mississippi when it ran through the oxbow lakes, Figure 133. How does the channel of 1896 differ from that of 1882?

The shifting of the channel may be checked by protecting the outer bank with stone or wood, but this is expensive. Rising floods may be held back by dikes or levees built on the plain a little distance from the river banks. When the levees are overtopped or breached widespread floods may result, such as occurred on the Mississippi flood plain in April, 1897, when about 13,000 square miles of the plain (two fifths of the entire area) were under water. The value of live stock and crops lost in this flood was estimated at $15,000,000; many thousands of people were for a time driven from their homes.

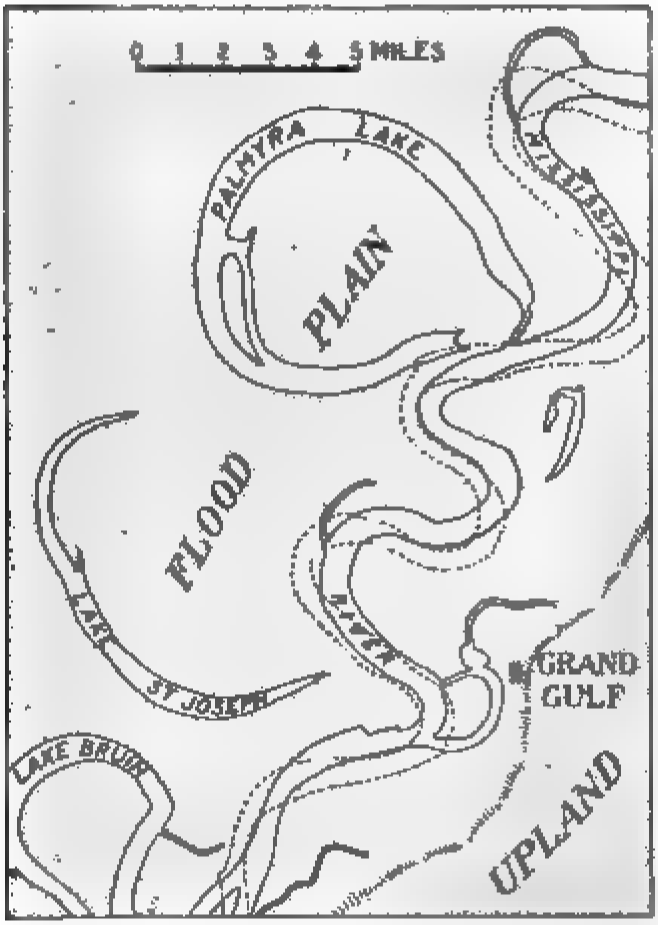

Fig. 133. Meandering Channel and Oxbow Lakes in the Flood Plain of the Mississippi, according to Surveys in 1882 and 1883. The position of the channel according to surveys in 1895 and 1896 is shown by dotted lines.

In March, 1890, a strong flood in the lower Mississippi broke through the levees on the left bank, forming the

"Nita crevasse" (a break on the Nita plantation), flooding the plain, carrying river silt into the shallow waters of the Gulf of Mexico, and ruining the oyster beds east of the delta.

152. Alluvial Fans of Large Rivers.—When rivers flow from mountains or plateaus and enter open lowlands, where no valley walls inclose them, they may build extensive alluvial fans of faint slope. The Merced river of California (see *M*, Figure 134) offers a good illustration of this habit.

The Merced gathers much waste from its steep headwaters in the Sierra Nevada. On issuing from its narrow valley at the mountain base it is free to run in any direction — forward, to the right or to the left — on the broad "valley of California," a belt of low country between the Sierra and the Coast range. Here the river, flowing first in one direction, then in another, has built a fan about forty miles in radius, of gravel near the mountains, of fine silt farther forward.

As the rain of this region falls chiefly in winter, it is necessary to irrigate the fields for summer crops. Nothing could be better adapted to the needs of irrigation than a gently sloping alluvial fan; for the river may be easily turned into various channels at the head of the fan and led forward on different courses, and thus distributed over thousands of acres.

One of the largest alluvial fans in the world is that of the Hoang-Ho, in eastern China. This great river, bearing a heavy load of fine silt from the basins among the

inner mountains, issues from its inclosed valley 300 miles inland from the present shore line, and at a height of about 400 feet above sea level, and then flows to the sea down the gentle slope of its extensive fan.

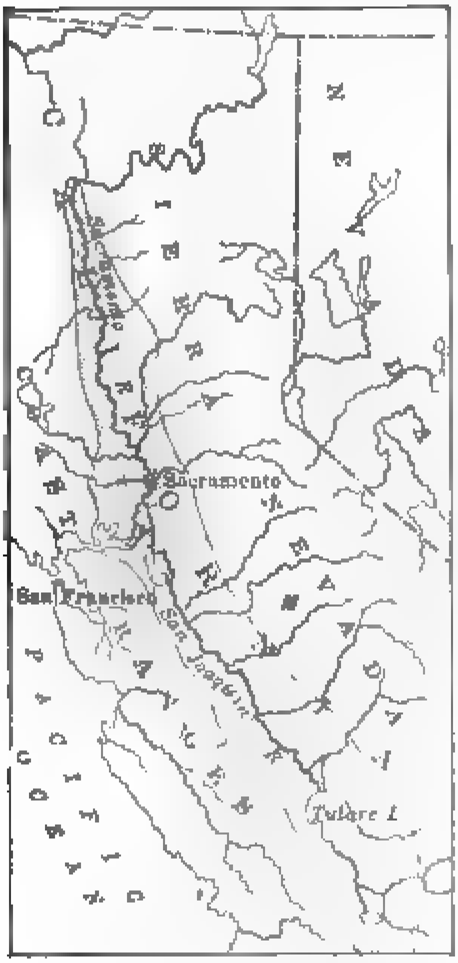

FIG. 134. The Valley of California

The great fan of the Hoang-Ho is very fertile and supports one of the densest populations on the earth; but it is subject to overflow on a vast scale, when the river suddenly changes its course from one path to another and invades fields and villages on a new course to the sea. Overflow is prevented as far as possible by dikes; but the channel has repeatedly been changed during the many centuries of Chinese history.

The loss of life caused by these overflows is very great. Not only are many thousands of people drowned, but the crops are destroyed over large districts, causing famines in which many more thousands perish.

153. Broad Plains formed by Rivers. — When many rivers flow forth from mountain valleys upon a neighboring lowland their adjoining fans unite in a broad plain sloping gently forward from the mountain base. This may be called a river-made plain. It resembles a coastal plain in

having higher land for a background, but it does not necessarily front upon the sea, and it is generally but little trenched by the rivers that built it. A plain of this kind often occupies the depression between two highlands or mountain ranges.

The many rivers issuing from the valleys of the Sierra Nevada and the Coast range upon the "valley of California" have formed an extensive plain, of which the Merced fan, described above, is only a part. The successive fans are very broad and flat, so that their slightly convex form can hardly be seen. The fans from the east and west meet in a flat-floored trough, Figure 134.

FIG. 135. Torrent Fan Delta, Lake Geneva, Switzerland

154. Deltas. — When a river enters a lake or the sea its current is checked. The finest part of the waste may be swept away by waves and tides; the rest accumulates at the river mouth and builds up a new land surface, called a *delta*, in advance of the original shore line. The fans of mountain torrents form deltas in lakes at the mountain

base. Small deltas are characteristic of young rivers; the longer the progress of river growth, the larger the delta may become.

The land surface of a delta is built on the same slope as that of the river flood plain farther upstream, the delta being only the forward part of the flood plain. Under water a delta slopes at a steeper angle than above water.

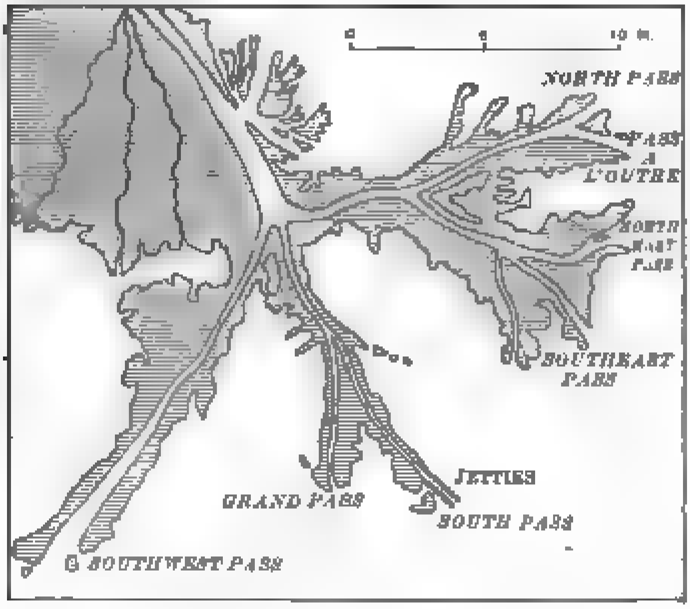

FIG. 136. The Delta of the Mississippi

The great fan of the Hoang-Ho may be regarded as its delta, because it has been built forward into the Yellow sea (so named from the color given by the river waste).

A river frequently splits into several channels on its delta, the outgoing branches being known as *distributaries*. These are well exhibited in the fingerlike divisions of the Mississippi on its outer delta, Figure 136, and in the many channels of the Ganges and the Brahmaputra on their deltas at the head of the Bay of Bengal. How many distributaries are shown in Figure 136?

Great rivers may build their deltas in the face of waves and tides. At the Mackenzie delta the tidal range is three feet, at the Niger four feet, at the Hoang-Ho eight feet, at the Ganges-Brahmaputra eighteen feet. The building of deltas by small rivers is favored by the protection from

waves in bay heads and by the weakness or absence of tides. Where are the above-named rivers?

The absence of deltas at the embayed mouths of certain rivers is frequently not so much because the tidal currents sweep away all the river silt, as because there has not yet been time enough to build a delta since the embayments were formed by the depression of the coastal lands.

The lower valleys of the Delaware, Susquehanna, Potomac and neighboring rivers are drowned, forming bays in the partly submerged coastal plain of the Middle Atlantic States. Whatever deltas these rivers previously built are now beneath the sea. Very little delta growth has yet taken place at the bay heads; hence the depression of the region is relatively recent.

The deltas of large rivers consist of fine-textured waste or silt, worn during the long journey from the river headwaters and weathered during many rests in the flood plain on the way. In a favorable climate deltas are very fertile and attract a large population. The three densest populations of the world (outside of large cities) are in eastern China, northeastern India, and northern Italy, all on the lower flood plains and deltas of large rivers.

155. Mature Rivers. — When a river and its larger branches have destroyed their lakes and falls and reduced their valleys to graded slopes, when all the side valleys join the larger valleys at grade, when the larger streams have broadened their valley floors so that they can meander freely upon flood plains in curves appropriate to their volume, and when a delta is built forward at the river

mouth, the river system has reached the mature or full-grown stage of its development.

Mature rivers accomplish the drainage of their basins and the carrying of rock waste to the sea in the most perfect manner. No undivided uplands remain from which a great part of the rainfall may be returned to the atmosphere by evaporation. The largest possible share of the rainfall is shed from the well-carved surface of the land and runs off in the streams with no delay in lakes or haste in falls. No hard rock ledges remain to be worn down in the valley floors. Everywhere the waste of the land is washed down the slopes to the streams and delivered in such quantity that the streams are kept working at their full capacity to transport the waste toward the sea.

The valleys of mature rivers are easily followed by roads and railroads; they are broad enough to contain cultivated fields as well as villages and cities, as in Plate X.

156. Old Rivers. — If no disturbance occurs, a maturely developed river system passes by slow degrees into a quiet old age. The hills waste away to fainter slopes and yield less and less waste to the streams. The texture of the waste becomes finer and finer. More of the waste is carried in solution.

The extreme old age of a river system would be characterized by low and ill-defined divides between faint slopes leading to broad flood plains, on which the streams would meander with great freedom. An increasing share of the transported waste would be dissolved. A large amount of rainfall might be lost by evaporation on the gentle slopes.

It is unusual to find an old river system. The lower trunks of large river systems often gain very gentle slopes and free-swinging meanders, but before old age is attained by all the small side branches and the headwaters movements of elevation or depression generally occur in the earth's crust, with more or less tilting and breaking; and in this way the rivers are made young again and set to work at new tasks.

157. Revived Rivers. — At any stage in the erosion of a region drained by a river, the river basin may be uplifted to a greater height above sea level. Then the river will at once begin to cut its valley floor deeper than it could have done before. Such rivers may be called *revived.*

Old rivers flowing across low worn-down mountains are rare, but revived rivers flowing through gorges in uplifted lowlands of this kind are common. The rivers and their narrow valleys in the Piedmont district of Virginia are thus explained.

If a meandering river is revived, it will intrench itself beneath its former flood plain; then its new valley will be regularly curved after the pattern of its meanders.

The north branch of the Susquehanna follows a deep and winding valley of this kind through the Allegheny plateau of northern Pennsylvania. The Osage has an extremely serpentine valley in the uplands of central Missouri. Both these rivers seem to have learned to meander when the uplands were lowlands. Since these regions were raised the rivers have cut down valleys of a meandering pattern. The valleys are still narrow. The rivers are

enlarging their curves by cutting away the outer bank; here the river is bordered by steep bluffs. Strips of flood plain are beginning to form on the inside of the river curves where the banks are low and flat.

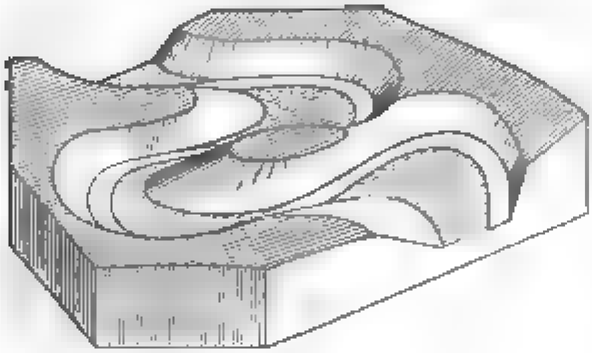

FIG. 137. Diagram of a Narrowed Spur in a Meandering Valley

Draw a map of the district shown in Figure 137. Describe the form and arrangement of the patches of flood plain. Where are the valley sides steep? Where are their slopes gentler?

It sometimes happens that a revived meandering river, eroding its outer bank, may wear through the neck of the narrowest upland spurs that enter its trenched course; it will then desert a roundabout course for a more direct one, Figures 137, 138. Rapids will occur for a time at the cut-off.

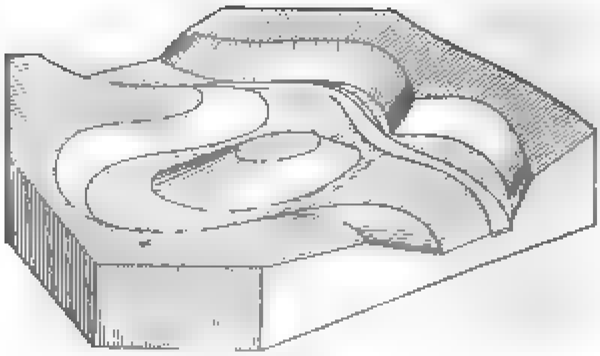

FIG. 138. Diagram of Cut-Off Spur in a Meandering Valley

Draw two maps of the district shown in Figure 138, one showing the path of the river just before the cut-off was made, one just afterwards. Compare the first of these maps with the one drawn from Figure 137.

The village of Lauffen (Rapids) on the river Neckar in southern Germany gains water power from rapids formed at a recent cut-off. The former course of the river is seen in a meadow beautifully curved around an isolated hill,

the cut-off end of an upland spur, Figure 139. Another cut-off spur is seen near the village of Hofen.

158. Water Gaps.—Many rivers cross the hard-rock ridges of the Allegheny mountains of Pennsylvania in sharp notches, called water gaps. For example, the Delaware river gathers many branches from the open valleys of northeastern Pennsylvania and escapes by a deep, narrow notch, called the Delaware water gap, in Kittatinny mountain, at the northwestern corner of New Jersey.

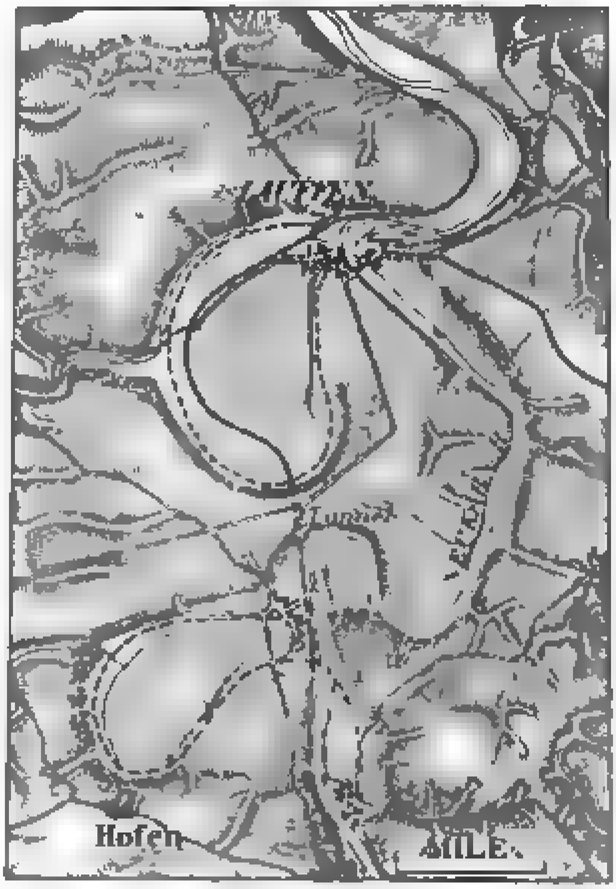

FIG 139. Intrenched Meanders of the Neckar

Such cases are explained as follows. Once the whole region stood lower than now and a lowland spread far and wide at about the level of what are the ridge crests to-day.

With the elevation of the region all the revived rivers begin to wear down their valleys. Where a trunk river cuts down its new valley across the belt of hard rock that is to make the mountain ridge, the valley remains narrow for a very long time; but elsewhere the valleys of the trunk and

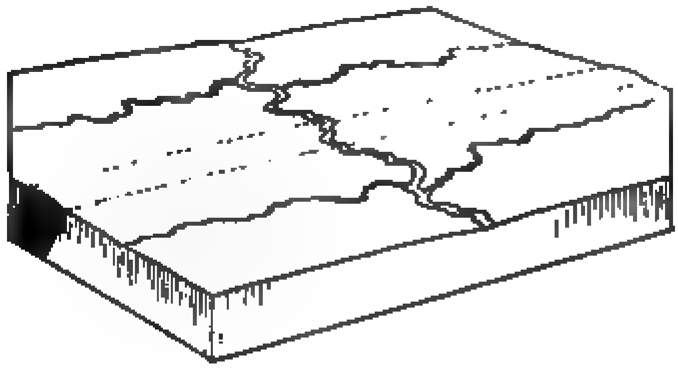

Fig. 140. Transverse and Longitudinal Streams

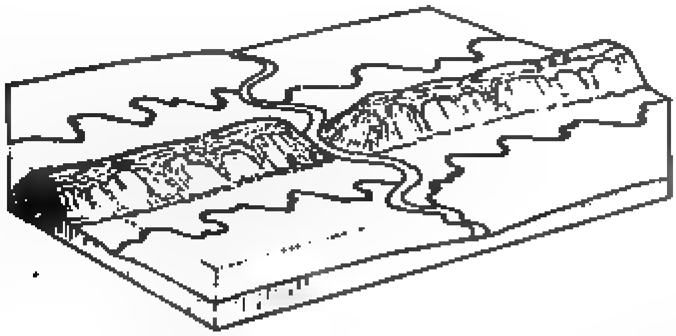

Fig. 141. Transverse and Longitudinal Valleys

branch streams widen rapidly in the weaker rocks, and in time all the hills of the weak-rock belts are worn away, leaving a lowland on each side of the hard-rock ridge, through which the water gap has been cut, as in Figure 141.

This explanation applies to the Susquehanna, cutting gaps in the Allegheny ridges, Figure 142, and to the stream that has cut a deep passage in one of the Allegheny ridges in Maryland, shown in Plate IX.

Fig. 142. Water Gap of the Susquehanna above Harrisburg, Pennsylvania

Where must one stand in Figure 141 to gain a view like that of Figure 142? How many water gaps are shown in Figure 103?

QUESTIONS

SEC. **134.** How is the rainfall of a region disposed of? What is ground water? Under what conditions will much of the rainfall be evaporated into the air? discharged by streams? absorbed by the ground? What is the run-off? Of what value is ground water?

135. How are caverns generally formed? What is a sink hole? What effect have sink holes on surface streams? Describe an underground stream. Describe the animals of caverns. What is the origin of the Natural bridge of Virginia?

136. What is a spring? Upon what does the variation of stream volume depend? Under what conditions is the variation small? Describe the movement of ground water. Where is it found at a small depth? To what depth should wells be dug or bored? Why is spring water purer than stream water?

137. What is an Artesian well? How is its water supplied? Name some districts where such wells are common. What is the relation of certain Artesian wells in eastern Maryland to Chesapeake bay?

138. Explain hot springs. Why are they commonly charged with mineral salts? Of what value are they? Name some examples.

139, 140. What is a geyser? Where are the most famous geysers? Describe and explain the action of geysers; of mud volcanoes.

141. Define river, river system, river basin, divide, channel, bed, banks. What is meant by a continental divide? by undivided drainage? by subdivides? What features of a river system have you seen illustrated in a small way?

142. Describe a river flood. Where is the river-borne waste laid down? How is a river supplied after a flood subsides? How does a drought affect ground water? springs? streams? Compare the streams of the rainy and of the drier parts of the United States.

143. Give some examples of the work of rivers from earlier chapters. Upon what does the depth to which a valley may be cut depend? How do slope and volume affect the velocity of a stream and its load of sediment? Why does a river carry more sediment at

time of flood? How is erosion performed by rivers? What is the source of the rock waste borne by rivers? In what sense is it said that "rivers erode their valleys"? Under what conditions may a river be called young? old? mature?

144. How is the course of a young river determined? What work is done by young rivers? What are the characteristics of young rivers? Describe the St. Lawrence system; the drainage of the Laurentian highlands; that of the region of the great African lakes. What changes occur as a river passes from youth to maturity?

145. How are lakes converted into rivers? Illustrate by Lake Geneva. In what part of the life of a river system are lakes most common? How do lakes affect the transparency and the steadiness of flow of their outflowing streams? Compare the Ohio and the St. Lawrence as to floods.

146. Where are falls and rapids formed in young rivers? How are gorges formed? Illustrate by the gorge of the Niagara; by the Yellowstone canyon. How do differences in rock structure determine the occurrence of falls or rapids? What uses are made of waterfalls?

147. Describe a torrent. What determines the least slope to which a river can wear down its course? Describe a graded river. Where have graded streams a relatively strong slope? Why? Where have they a very faint slope? Why? State the slope and the load of the lower Mississippi.

148. Where are graded reaches first developed in a river? Where do rapids survive longest? What is a local baselevel? In what condition are the rivers of New England? What other region has similar rivers? Describe a river that has long been undisturbed. Describe the stream slopes in a well-graded river system. How do its branches join its trunk? Why are they thus related?

149. Describe the valley of a young river. What disadvantages does it present to occupation? How do floods act in such valleys? Illustrate from the Allegheny plateau. How is a valley floor widened? What changes do the valley sides suffer? What advantages are presented by a widened valley?

150. Describe the action of a winding stream. Describe its valley when grade is reached. What changes occur after grade is reached? Compare the outer and inner sides of river curves. Where and in what pattern is the flood plain first developed? Describe the later changes in the valley spurs; in the flood plain. Where is the most silt laid down during a flood? How does this affect the form of a flood plain? How does a heavy load of waste affect the behavior of a river? Give an example.

151. How does a light load affect the course of a river and the slope of its flood plain? What are meanders? What is the derivation of this term? On what does the size of meanders depend? How does their form vary? How has the course of the Mississippi changed? How have these changes affected its flood plain? What is an oxbow lake? Describe an example. How is the shifting of a river channel checked? How are flooded rivers restrained? Describe the effects of the Mississippi flood of 1897. Describe the Nita crevasse.

152, 153. Describe the fan of the Merced river. Why is irrigation needed here? How is it favored? Describe the fan of the Hoang-Ho, and its relation to the people of China. Describe a river-made plain. Give an illustration from California.

154. How are deltas formed? What is the relation of a delta to a flood plain? What are distributaries? Describe some examples. What is the relation of deltas to tides? Give examples. Why are deltas wanting at certain river mouths? Give examples. What is the relation of large deltas to population?

155, 156. What are the features of mature rivers? Describe the work of mature rivers; the change from a mature to an old river; an old river system. Why is it unusual to find old rivers?

157. What is a revived river? Describe the rivers of the Piedmont belt in Virginia. Describe the valley of a revived meandering river. Give two examples. What changes may happen in such valleys? Illustrate by the Neckar.

158. What is a water gap? Give an example. Explain it. What is the origin of the lowland upstream from a water gap?

CHAPTER IX

DESERTS AND GLACIERS

159. Land Forms dependent on Climate. — In regions of ordinary climate the snow of winter melts in the spring, and the droughts of summer are not severe enough to make the surface barren by preventing plant growth. The form of such regions is determined largely by the action of streams and rivers, whose work goes on steadily along branches and trunk so that, in the course of ages, the land surface is dissected and a mature system of branching valleys is carved. Many examples of regions of this kind have been given in the descriptions of plains and plateaus, mountains and volcanoes.

An excellent illustration of a well-dissected upland is found in the Ozark plateau of southern Missouri. The once even plateau has been transformed into a succession of rounded hills and spurs of graceful form, separated by a multitude of branching valleys. The maturely dissected surface has much less strength of relief than the plateau of West Virginia; its slopes are usually of moderate steepness; it is a fertile agricultural district. Villages are generally on the uplands, for most of the valleys are as yet too narrow to attract settlement. Many other examples might be named in which well-established branching valley systems testify to the long duration of an ordinary or normal climate.

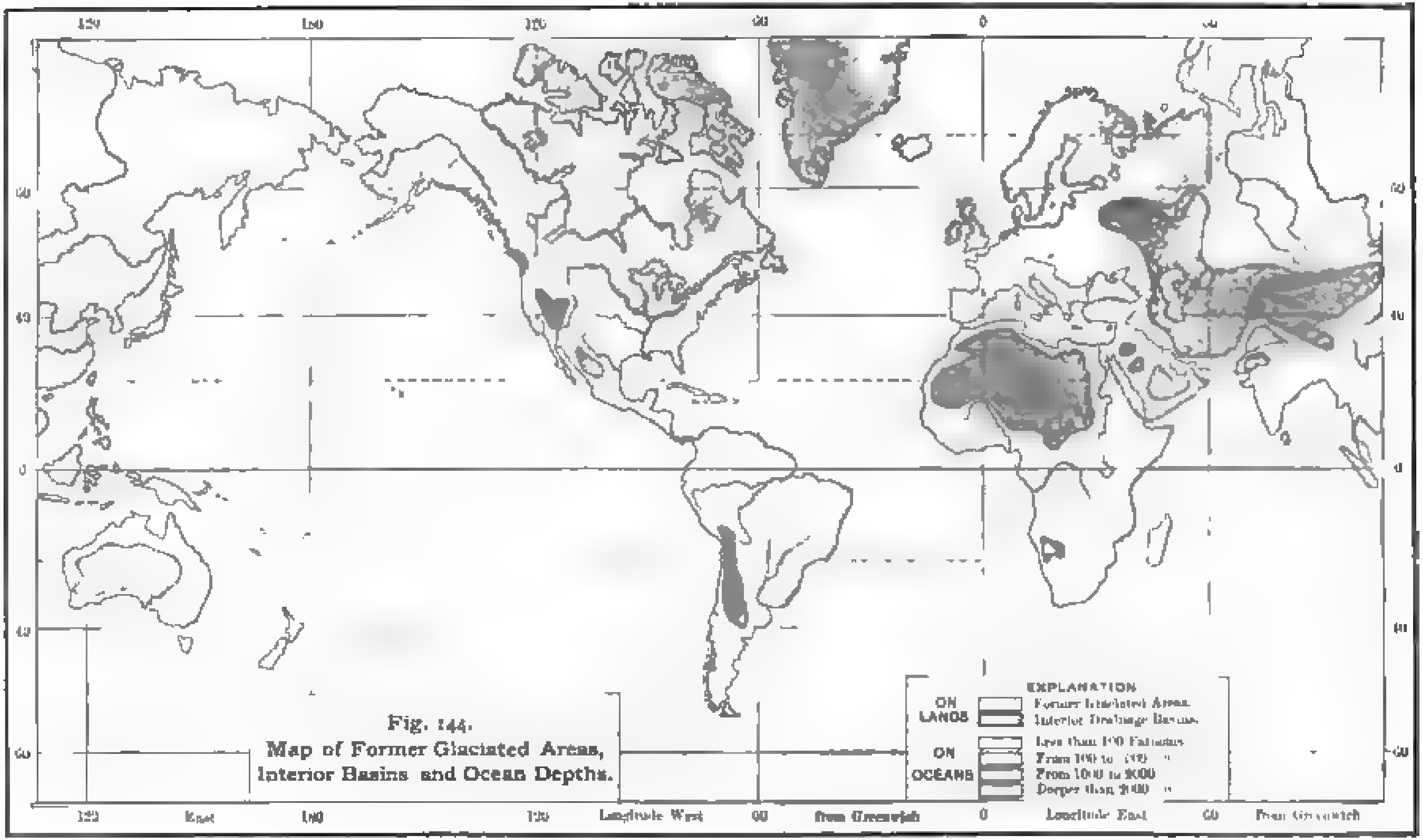

Fig. 144.
Map of Former Glaciated Areas,
Interior Basins and Ocean Depths.

In certain other parts of the world the climate is so dry that vegetation is scanty or wanting, and the surface is left barren and desolate. Here streams flow only at rare intervals, the rivers frequently fail to reach the ocean, and the wind becomes an important means of moving land waste.

In still other parts of the world the mean annual temperature is so low that the snowfall is not all melted away

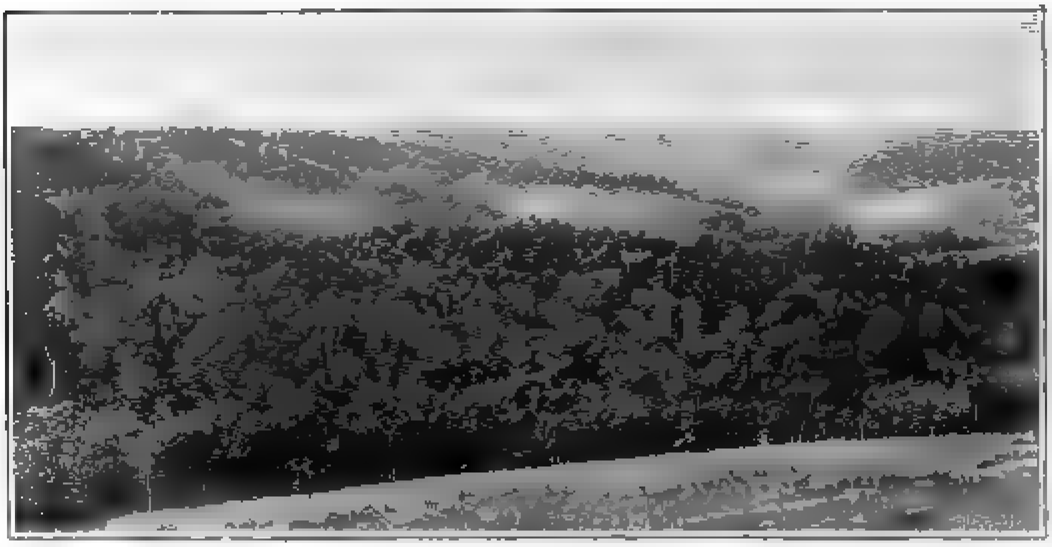

FIG. 143. The Ozark Plateau, Missouri

in the warm season. The snow thus gathers from year to year, and, as it thickens, the under part is slowly compacted into ice. The ice has become thick enough to behave like a viscous body and to creep slowly down the slope of the land until it enters a warmer climate, where it melts away. Such moving sheets or streams of ice are called glaciers. Regions thus covered with ice and snow are even more barren than arid deserts. The removal of rock waste is there chiefly performed by ice instead of by rain and rivers.

160. Deserts. — It has been explained in the paragraphs on rainfall that the arid deserts of the world occur under the drying trade winds, on the slopes and lowlands to the leeward of high mountain ranges, or in inclosed continental interiors. (See page 71.) The interior basins of Nevada and Utah, inclosed from moist winds by the ranges of the Pacific slope, fall under the third class, although they are less arid than many parts of the Sahara.

All of these deserts are hot in summer, but they may be cool or cold in winter. They should therefore be thought of as prevailingly dry regions which may be hot or cold according to the season of the year. The deserts of central Asia have a mean January temperature of only 10° or 20° F.

Rain seldom falls, and the dry air parches the dusty, sandy, or stony ground, so that plant life in deserts is scanty, though it is rarely altogether absent. Rock waste is plentifully exposed on open spaces between the scattered desert plants, instead of being covered by a close growth of grass, bushes, or trees, as in regions of more favorable climate.

Deserts are of all forms, — mountains, plateaus, and plains; but desert plains are the most extensive. The desolate gray forms of desert mountains, like the ranges of northwest Mexico (Sonora) and of northern Chile (Atacama), are much less picturesque than mountains with snowy summits and forested flanks in a moister climate; but the wet-weather torrents of desert mountains have furrowed them with deep ravines like those of forested mountains.

161. Streams of Dry Climates. — When a light rain occurs in a region of dry climate much of the water returns to the atmosphere by evaporation, a large part of the remainder sinks into the thirsty soil, and the run-off by streams is small. Much of the ground water evaporates underground and passes out from the soil as vapor, instead of coming out in springs. When a heavy rain occurs, as occasionally happens, water is supplied faster than it can soak into the ground, surface rills form everywhere, and the streams are quickly flooded; but the floods soon run away, leaving the channels empty and dry again.

The streams of dry regions are, therefore, very variable in volume; active for a while after a rain, almost or quite disappearing in the long dry seasons; advancing far down their lower courses when in flood, then dwindling and withering away and leaving their lower channels dry.

In the Sahara dry water courses, known as *wadies*, are commonly used for roads, as their gorges frequently offer graded ways through rocky uplands. Death by drowning would nowhere be so little expected as in a desert; but it sometimes happens that a caravan, following a wady through an upland, meets a down-rushing flood, and before the travelers can climb the steep walls of the gorge they may be overwhelmed and drowned.

In parts of the Rocky mountain region, of generally dry climate, heavy rains occasionally fall in summer. Then for a few hours the dry channels are flooded with a rushing turbid stream, which sweeps away the waste that has been washed in by lighter rains. Camping parties, pitching their tents too near a channel that is almost

161. **Stream**[illegible]

occurs in a [illegible]

returns to the [illegible]

the remainder [illegible]

streams is [illegible]

underground [illegible]

of coming [illegible]

occasionally [illegible]

soak into [illegible]

the stream [illegible]

away, leaving [illegible]

The [illegible]

in volume [illegible]

disappearing [illegible]

their [illegible]

withering [illegible]

In [illegible]

dry in the afternoon, may be overwhelmed by a rushing flood at night. Opposite the mouths of canyons, streams of coarse waste, including bowlders weighing many tons, are spread forward by floods from cloud-bursts in the mountains,—"immense, sudden, deluging rain storms, which at rare and exceptional moments discharge their waters into

FIG. 145. Flood in Cherry Creek, Denver, Colorado

one of these mountain gorges. On such occasions bowlders six or eight feet in diameter are swept down the canyon in a fearful rush, and are sometimes carried out on the . . . slope for half a mile."

Figure 145 illustrates a sudden flood in Cherry creek, where it passes through the city of Denver, Colorado. The channel of the creek was dry half an hour before this raging torrent appeared.

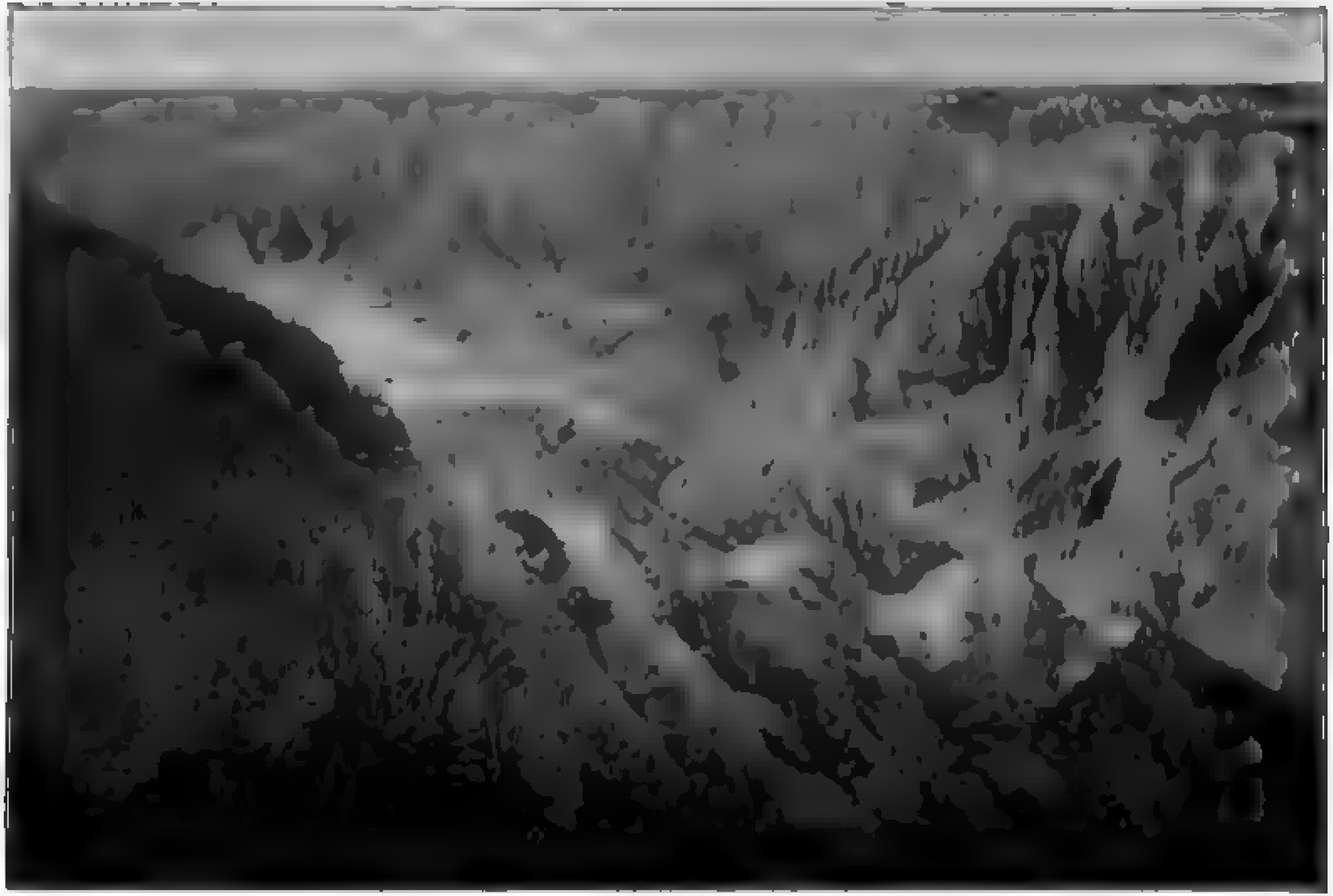

PLATE XII. Bad Lands in the Great Plains, South Dakota

Streams that are supplied by springs in arid uplands and mountains frequently diminish in volume, partly by evaporation, partly by sinking into the ground, as they advance over desert lowlands. They may wither away and disappear entirely from the surface; but their flow is usually continued as ground water for some distance beyond their visible end. Their load of waste is spread on the surface before them in the form of an alluvial fan. Many such streams are known around the mountains of Utah and Nevada. The depressions between the ranges are floored with fans and plains of waste that has been washed from the mountain ravines in time of flood.

162. Bad Lands. — Arid regions of weak, fine-textured strata are often minutely carved by the wet-weather rills and rivulets bordering their chief valleys. This would not happen in a moister climate, for there the abundant plant growth would protect the surface and prevent the active run-off of the wet-weather rills; but in an arid region, where plants are few or wanting, every little wet-weather rill erodes its own little ravine in the barren surface.

Western Nebraska offers many examples of uplands that have been elaborately dissected in this way. Plate XII exhibits the delicately carved sides of a young valley in an even upland. Sharply carved forms of this kind are known as *bad lands* because of the difficulty of crossing them.

163. Interior Basins and Salt Lakes. — The larger rivers of interior regions do not entirely wither away in their channels, but continue until they reach a depression or basin between the uplands. There the waters spread out, forming a

lake. Evaporation from the lake surface discharges as much water into the air as is received from the inflowing streams.

In regions of more abundant rainfall the streams from a moderate drainage area suffice to fill lake basins to overflowing. The Great lakes of the St. Lawrence system gather their water from a comparatively small area around each basin, yet they are always full, up to the outlet notch in their rim. In desert regions rainfall is so scanty and evaporation is so active that the streams from a large drainage area may form only a shallow lake, occupying a small fraction of its drainage area.

Lakes of the latter kind are usually salt, for all the saline substances gathered in small quantity by their rivers accumulate in the lake and may in time constitute a fifth or even a third, by weight, of the lake contents.

Great Salt lake of Utah, with about eighteen per cent of salt, is of this kind. It lies on the lowest part of the waste plain that has been built up in the depression among several mountain ranges. Its waters are so dense that a man's body will not sink beneath the surface. The Dead sea, with twenty-four per cent of salt, is one of the most famous salt lakes, occupying a long narrow depression in Palestine. Lake Van, in eastern Turkey, containing thirty-three per cent of salt, is the densest water body known.

Interior basins, from which no rivers escape to the sea, receive the waste that the slopes of the inclosing mountains lose. The floors of the basins are in this way built up and smoothed. By the wearing down of the mountains and the filling of the basins the relief of the region as a whole is decreased. (See Figure 144.)

The level of the Dead sea is almost 1300 feet below that of the Mediterranean, and the bottom of the trough occupied by this sea is about 1300 feet deeper still. Ravines in the border of the uplifted plateaus lead down to stony fans that are advancing into the sea. The great depth of the water and the moderate extension of the fans show that the basin contains much less waste now than it will in the future.

A great part of Persia consists of large basins inclosed by mountains and without outlet to the sea. Long waste slopes stretch forward five or ten miles with a descent of 1000 or 2000 feet, stony near the mountain flanks, and gradually becoming finer textured and more nearly level farther away. The central depressions are deserts of drifting sands, with occasional salt lakes. The population gathers around the margins of the basins where the dwindling streams are still running, avoiding the rugged and barren mountains on the one hand, and the uninhabitable central plains on the other.

Central Asia repeats the same conditions on a still larger scale. The basin of Eastern Turkestan includes in its central part many low ranges that have been half buried with waste from the higher inclosing mountains. Many rivers flowing from the mountain rim wither on their way toward the chief central depression; only the largest river (Tarim) reaches it, there spreading out in the marshy Lake Lob. The chief settlements are near the border of the basin, where the larger rivers come out from the mountains and where their waters can be used for irrigation.

164. Wind Action in Deserts. — Where the land surface is covered with vegetation the wind has little effect on the form of the ground. In arid regions where vegetation is scanty or wanting the wind becomes a powerful agent of change. The difference of wind action on a dusty road and on a grassy field may be taken to illustrate the contrast between wind action in regions of dry and of wet climate.

Wind storms in deserts raise the finest dust high into the air, drift along the sand at the bottom of the current, and rasp the unmoved stones and ledges with the drifted sand.

Even in calm weather whirlwinds are of daily occurrence in deserts during the hot season. They are formed by the whirling ascent of air that has been heated by the action of sunshine on the dry bare ground. Before the whirl begins the existence of the overheated layer of surface air is often indicated by a mirage.

Whirlwinds may raise dust more than a thousand feet into the air and drift it long distances before it settles. When violent winds blow, like the squalls which often precede thunderstorms in a moister climate, heavy clouds of sand and dust are raised from the desert surface, darkening the sky, and almost suffocating the traveler overtaken by them.

Vessels in the Atlantic west of the Sahara sometimes have their sails reddened with dust brought by the trade wind from the Sahara. Rain in southern Europe is occasionally reddened with dust brought by storm winds from the same source. It has been estimated that, during four

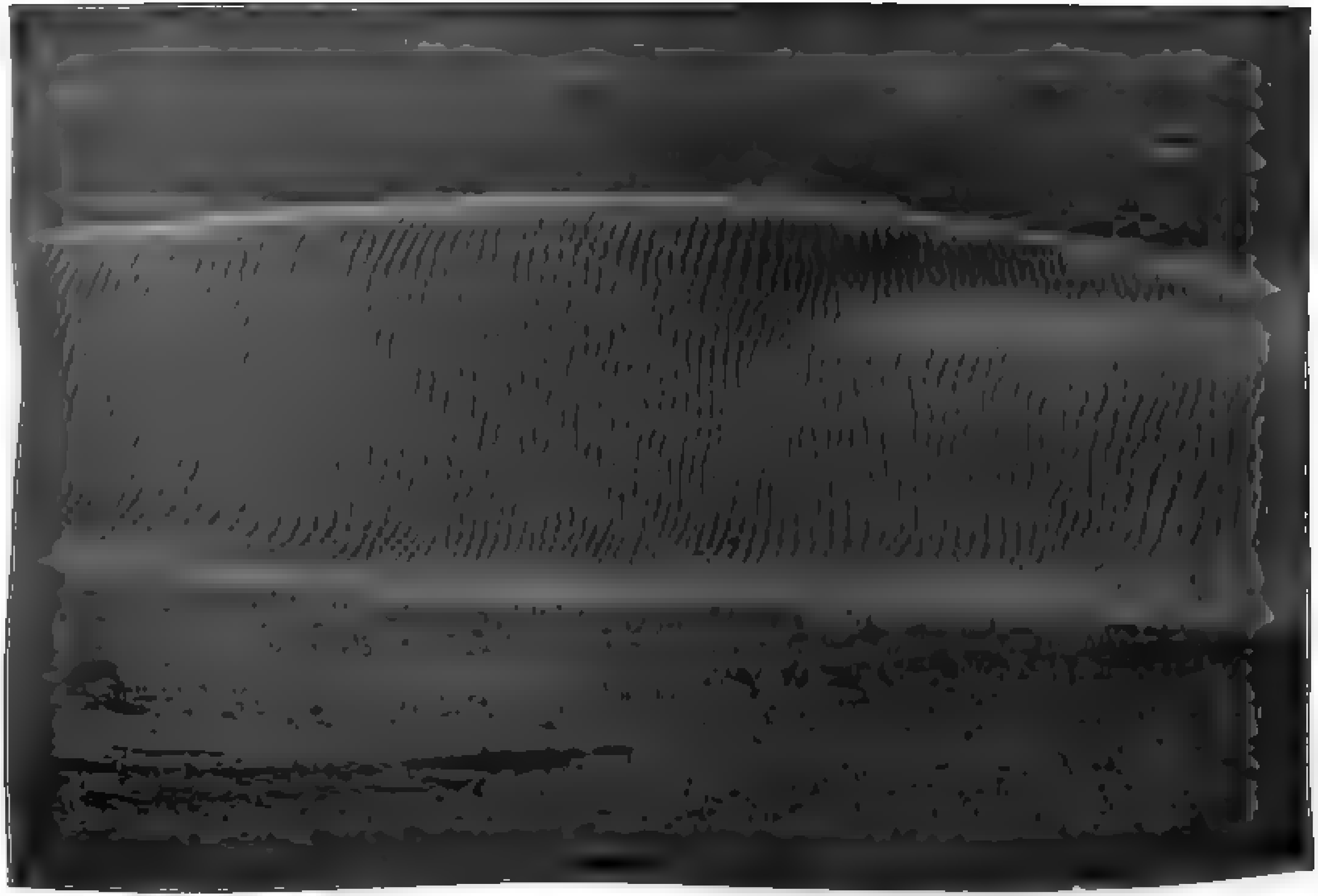

PLATE XIII. A Sand Dune rippled by the Wind

days of such winds in March, 1901, nearly 2,000,000 tons of dust from the Sahara fell on central Europe; the greater part reached the ground south of the Alps, but some of the dust was observed as far north as the Baltic sea. East of the deserts of central Asia extensive deposits of wind-borne dust have been formed; they constitute some of the most fertile districts in the Chinese empire.

Desert mountains and uplands are so well exposed to strong winds that the finer particles of rock waste are

FIG. 146. Sand Dunes in the Sahara

blown from them, leaving their surface rocky and stony. The finer particles settle chiefly in the depressions where the winds are less violent; here the surface is sandy or dusty.

165. Sand Dunes. — When the rocks of a desert are of a kind, like granite, that affords sand on weathering, the wind may blow the sand grains into drifts or dunes. Dunes sometimes grow to a height of from 500 to 600 feet. Their surface may be delicately rippled, as in Plate XIII. In a region of relatively steady winds the sand is blown up the windward slope and carried over the crest; hence the dune may slowly advance, gradually

changing its place and form. Dunes of drifting sand are usually more barren than other parts of a desert.

A group of dunes sometimes advances across a dry valley, concealing its form for several miles. When rain falls the stream from the upper part of the valley disappears as it enters the loose sand of the dunes.

Sand dunes occur also on low coasts where the winds frequently blow landward across a sandy beach. The dunes then form a belt of hills a little inland from the beach, as will be again referred to under shore forms.

166. Dry Regions, formerly Moist. — In some regions now arid, marks of a former moist climate are found. Certain basins now almost without water have been filled with great lakes, even to overflowing; the former shore lines of the lakes are marked by cliffs, beaches, and deltas, and an outlet is sometimes traceable in a trench across the lowest pass in the inclosing highlands.

The basin of Great Salt lake in northwestern Utah in prehistoric times contained a much larger lake, to which the name of an explorer, Bonneville, has been given. Its shore lines are still plainly recorded on the mountain sides nearly 1000 feet above the desert plain around the present lake; the foreground of Figure 86 shows an extensive beach of this lake. The channel of an outlet leads northward across a pass to the basin of Snake river; hence the former lake must have been fresh. The change from the moister climate of Lake Bonneville time to the drier climate of to-day has caused the almost complete disappearance of the lake waters, revealing the sediments of the lake floor in

an arid plain. The ancient lake deltas are now trenched by the streams that built them.

Another extensive lake (Lahontan) of very irregular outline and several smaller lakes once occupied the now desert basins of western Nevada.

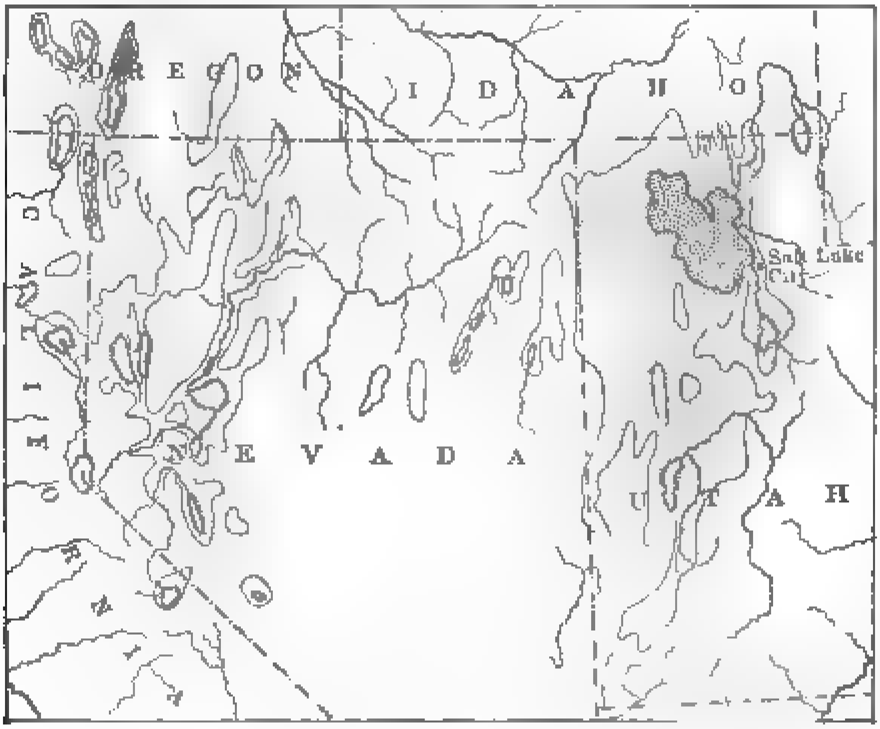

FIG. 147. Lakes Bonneville and Lahontan

Compare the area of Lake Bonneville and that of Great Salt lake (fine and coarse dots, Figure 147). How long is Lake Bonneville from north to south? How long is Great Salt lake from northwest to southeast? (Scale of figure, 200 miles to an inch.)

The causes of climatic changes of this kind are little understood, but their geographical consequences are of great importance. Extensive lakes among forest-clad slopes have been replaced by desert plains between arid mountains.

167. Salinas. — Certain basins that formerly contained salt lakes have now been more or less completely dried out, leaving marshy or dry plains of salt, known as ***salinas***, in the central depressions, avoided by all plant and animal life.

The Bolivian table-land, a lofty waste-filled basin lying between two great ranges of the Andes, holds Lake Titicaca in its northern part at an altitude of 12,500 feet. The outflowing stream runs 100 miles southeast to a marshy salina, fifty miles long. The water not evaporated here flows southwest and is lost in a broad salina of dazzling white surface. Somewhat farther south is a more extensive salina, 4000 square miles in area, a white and level plain covered with a layer of salt about four feet thick, impassable when wet, but firm in the dry season.

Salt lakes and salinas yield common salt and other minerals of commercial value. Great Salt lake is estimated to contain 400,000,000 tons of salt. These products would be of greater utility if they did not so generally occur in thinly populated desert regions.

168. Ice Sheets and Ice Streams. — In the polar regions the temperature even in the lower atmosphere is so low that snow and ice cover much of the land all the year round, even close to sea level, cloaking the ground with ice sheets. In the temperate and torrid zones it is only on mountains that the temperature is low enough for snow to be more abundant than rain, so that snow fields are formed on the higher slopes and ice streams in the upper

During winter in the northern United States there are frequent examples of the formation of small short-lived ice sheets, after a succession of snowstorms with prevalent cold weather and occasional thaws. Such an ice sheet is not thick enough to move; but if it should grow year after year to a thickness of 1000 or more feet, it would slowly move outward from the region of greatest height and thickness to lower ground in a milder climate. This is because ice is not perfectly solid; it moves toward its unsupported border very much as a thick mass of paste would move, but much more slowly.

169. Antarctic Ice Cap. — A few explorers of the far southern ocean have discovered a great ice sheet ending in cliffs that rise from 100 to 180 feet above the sea. No land was seen back from the top of the cliffs.

Although as yet known only on one side of the south pole, the ice sheet is thought to form a polar ice cap, perhaps 1000 miles in diameter. There may be some land on which the cap rests; but it is believed that much of it lies on the sea bottom. It must tend to thicken from snow supply over its desert plateaulike center; but it slowly creeps toward the free seaward margin, where great tables of ice break off and float away as icebergs. As far as this desolate region has been explored it is uninhabited.

170. The Greenland Ice Sheet. — Greenland is covered by a heavy sheet of ice, measuring about 1500 miles north and south and from 300 to 600 east and west. It has a slightly convex surface and probably rises to a height of 9000 feet in the central part. The ice sheet conceals

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the hills and mountains except near the margin, where the sheet is thinner; here occasional rocky summits rise above the surface like islands in a frozen sea.

Some of the Greenland glaciers (arms of the ice sheet descending toward or into the sea) are from ten to fifty miles broad. Their forward movement is from twenty to fifty feet a day. Many icebergs are formed of great fragments broken from their front. The interior of the ice sheet is a monotonous desert of snow and ice, now melting and becoming almost impassable, now freezing over or receiving a new layer of snow.

The only inhabitants of this great cold desert are a minute worm and a simple microscopic plant that sometimes gives a red color to snow. The Eskimos of Greenland live on the narrow belt of land between the ice sheet and the shore.

171. Alpine Glaciers.—Glaciers of the Alpine type flow slowly down in streamlike tongues from snow basins in the valley heads between lofty peaks and ridges.

The end of a glacier, melting as the ice descends to a milder climate than that of its gathering ground, often reaches below the tree line. Glaciers of this kind occur in the Alps, the Caucasus and Himalaya mountains of the Old World, and in the mountains of Canada, Alaska, and Patagonia in the New World. In Alaska many of the glaciers descend to the sea. The front of the Muir glacier, Plate XIV, breaks off in cliffs 200 feet high.

A glacier moves faster along the middle surface line [illegible]t its sides or bottom, thus resembling a river. The

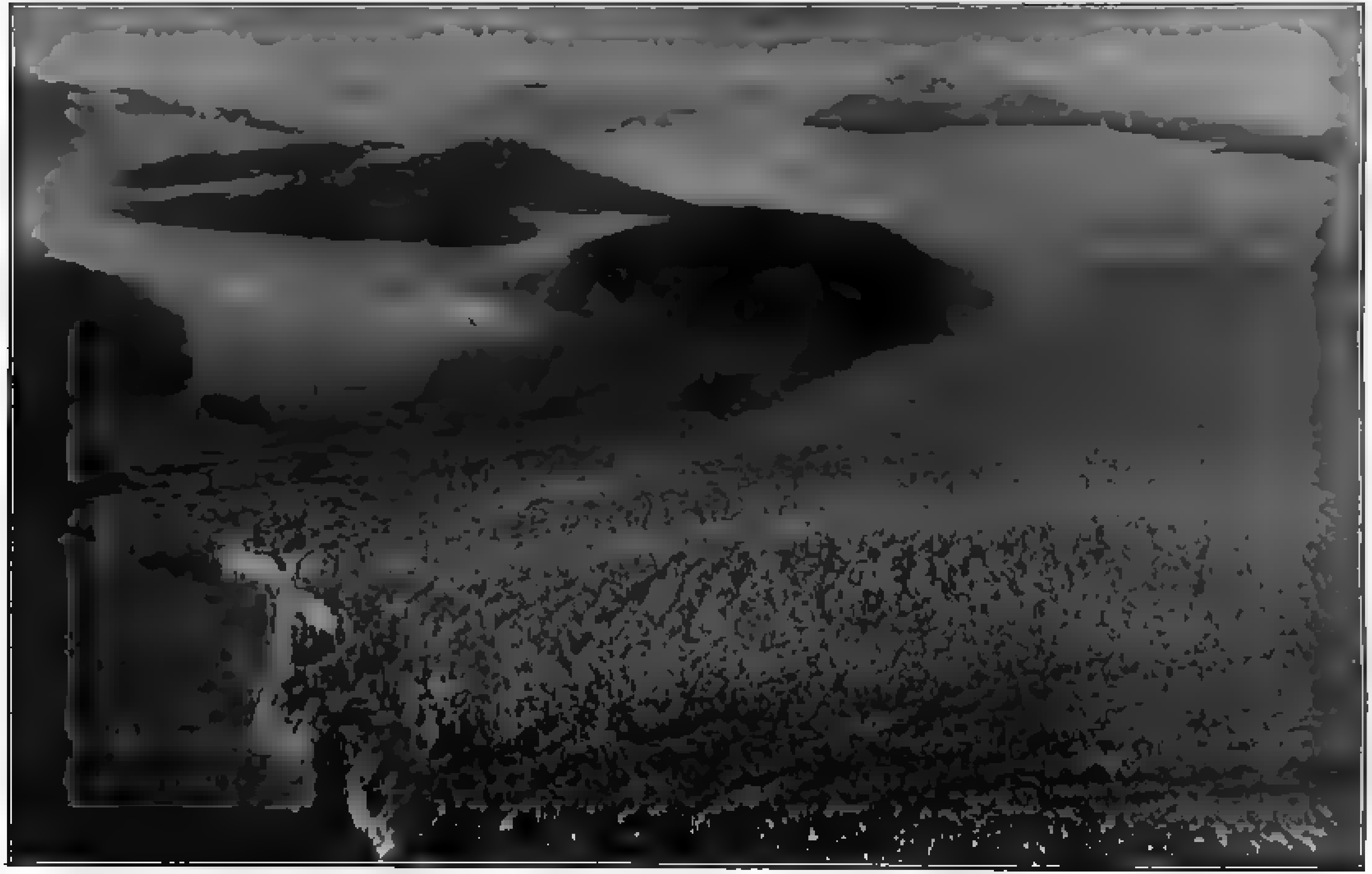


PLATE XIV. The Muir Glacier, Alaska

movement of Alpine glaciers is on the average from 100 to 500 feet a year.

Glaciers press heavily on their beds, dragging rock waste beneath them and scouring the bed-rock clean and smooth. Loose grains and fragments of rock, dragged along by the ice, scratch and groove the smoothed rock surface. The rock waste thus scoured from the ice floor, as well as that torn from projecting ledges and that received in rock slides and avalanches from surmounting slopes, is dragged or carried along by the ice and laid down around its lower margin or at its end, or washed away by the stream that issues from beneath the ice. Great bowlders may be carried on the ice.

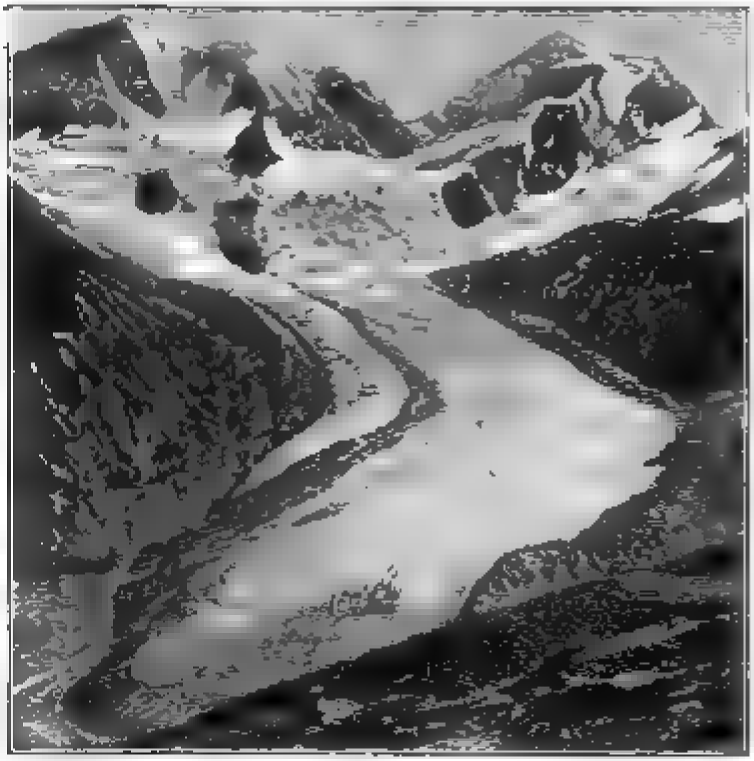


FIG. 148. Rosegg Glacier in the Alps

The ridge of rock waste that is ordinarily formed around the end of a glacier is called a terminal moraine; one is shown in Figure 148. Note the moraine that trails down on the Rosegg glacier from a rocky spur between two of its upper snow basins. It is called a medial moraine. Why does it not follow the middle of the glacier?

Describe the medial moraine of the Viesch (pron. *feesh*) glacier, Figure 149. From how many snow basins is this glacier supplied?

Large glaciers are sometimes so heavily covered with moraines near their lower end that a plant-bearing soil is formed upon them. Pasturage is found for the flocks of the mountaineers in the Himalayas on certain grass-covered moraines overlying the ice. Some Alaskan glaciers bear large forests on the moraines near their ends.

FIG. 149. Viesch Glacier in the Alps

Water received from side streams and supplied from melting ice gathers beneath a glacier and issues from an ice cave at its end. The water is usually whitened by fine "rock flour" ground beneath the ice.

172. The Work of Ancient Glaciers and Ice Sheets.—Certain parts of the world show the marks of ancient glacial action, although the climate there to-day does not allow snow to remain on the ground through the summer.

Ancient glaciers occupied certain valleys in the Rocky mountains of Colorado and in the Sierra Nevada of California. Great glaciers descending from the high Sierra into the

desert lowland in eastern California built strong moraines forward from the mountain base at the mouth of the valley.

Compare the glacier that once occupied the valley in Figure 150 with the Rosegg glacier, Figure 148.

Around the border of the Alps the lower land near the outlet of the chief valleys is often inclosed for ten or twenty miles from the mountains by a belt of hilly morainic ridges. The ancient glaciers that descended southeast from Mt. Blanc to the river-made plain of the Po built a huge terminal moraine, whose ridges rise from 1000 to 1500 feet above the plain and inclose a great amphitheater.

FIG. 150. Glacial Moraines, Sierra Nevada, California

The most extensive ice sheets of the glacial period were those that spread outward from the highlands of Canada across the basins of the Great lakes upon the northern part of the United States, and from the highlands of Scandinavia across the Baltic upon northern Germany. (See Figure 144.)

The highlands of eastern Canada, — the Laurentian highlands, — whence the ice sheets moved out to the surrounding regions, show much bare rock, clean scoured or covered

by a thin, stony, infertile soil. The hollows between the rounded rocky hills were often deepened by the ice, so that they now hold lakes or swamps, large and small. Besides many such lakes in rock basins, others are held behind barriers of rock waste or drift that was left irregularly over the surface when the ice melted away.

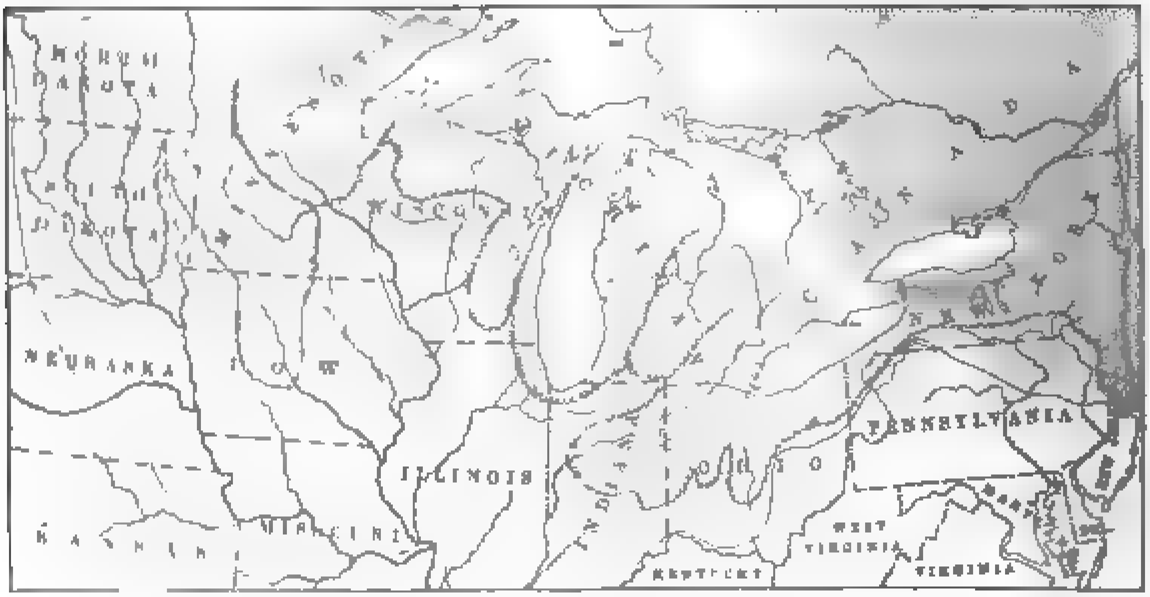


FIG. 151 Glaciated Area of the Northern United States

Much of the rock waste that has been swept from Canada by ice action is now found spread out in smooth plains, forming the fertile prairies south of the Great lakes. Rock waste that has thus been dragged along by ice action or washed along under or in front of the ice by streams is known by the general name of *glacial drift.*

The Scandinavian highlands and the lowlands of northern Germany exhibit the same relation to ancient glaciation that has just been described for the Laurentian highlands of Canada and the states bordering the Great lakes. The highlands are left with scanty soil and much bare rock;

the lowlands are sheeted over with drift, much of which is fertile farming country. The highlands remain in great part a wilderness, although scattered farms and small villages are found in the valleys. The lowland plain has a large agricultural population and many busy cities.

Among the most characteristic results of ancient glacial action are the rounded shapes of scoured ledges, Figure 152, and the irregular surface of the moraines, Figure 153.

FIG. 152. Ice-Worn Rocks, Coast of Maine

Terminal moraines of stones, gravel, and sand are strongly developed in the states south of the Great lakes. They form belts of hills commonly from three to ten miles wide; the hills are from fifty to two hundred feet high. The moraines are sometimes very uneven, with so many stony mounds and marshy hollows as to present a formidable barrier to travel. One may easily lose his way on such an undulating surface, where the hills are all much alike and where no conspicuous landmarks serve as guides.

Morainic hills are frequently dotted over with large rocks or bowlders, large and small, brought from some

FIG. 153. Glacial Moraines, North Dakota

more or less distant ledges by the ice; the bowlders are frequently unlike the rock on which the moraine lies.

FIG. 154. A Glacial Bowlder

Glacial bowlders are so plentiful in some parts of New England as to make the land there almost worthless.

Plate XV. A Troughlike Glaciated Valley in the Western Alps

173. Drumlins. — In some districts the rock waste has been gathered beneath the ice sheet in arched, oval hills called *drumlins*, commonly half a mile or more long and from 100 to 200 feet high, easily recognized when once known. They may be compared to sand bars in rivers or to sand dunes under the wind.

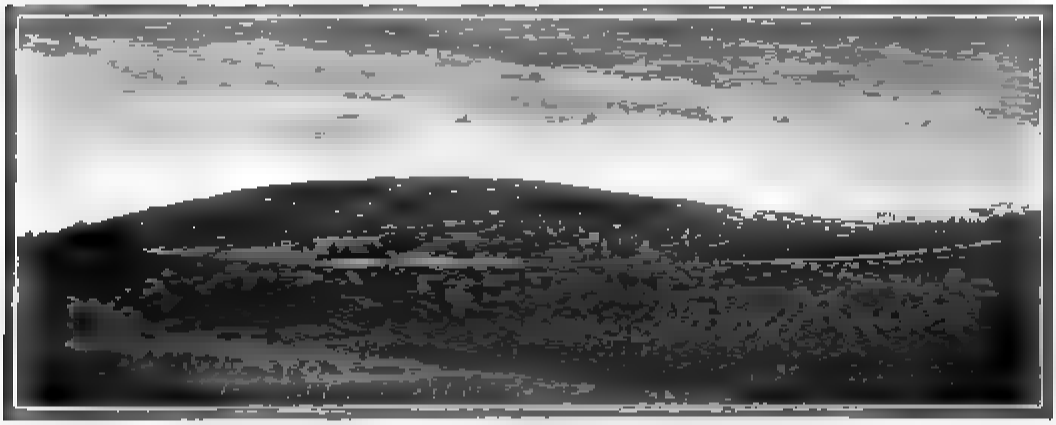


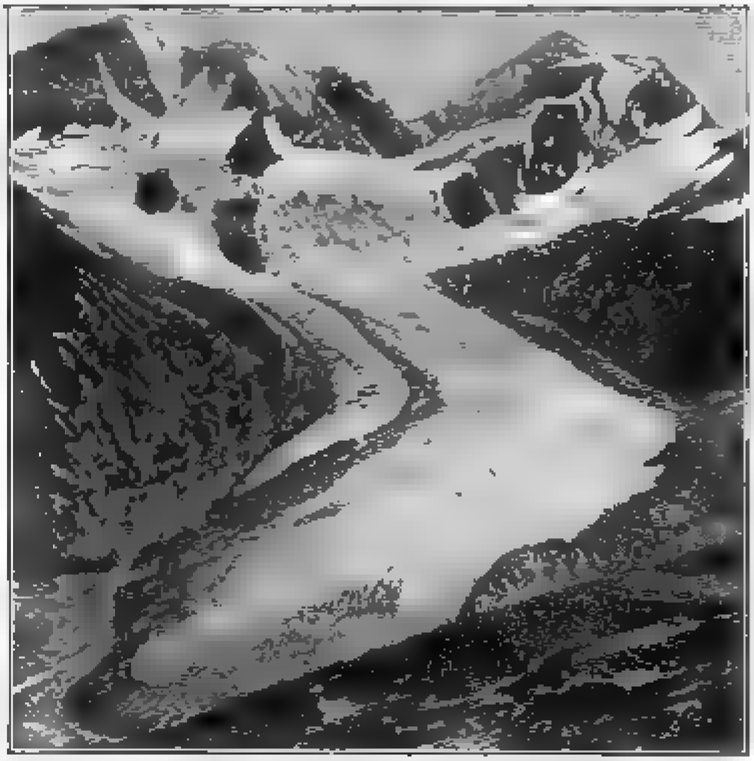
FIG. 155. A Drumlin, Massachusetts

174. Valleys, Lakes, and Waterfalls in Regions of Ancient Glaciers. — Some of the ancient glaciers of mountain regions were very massive, from 2000 to 5000 feet thick, and moved with relative rapidity down channels of rapid descent; here glacial erosion was most intense. The channels thus occupied are now seen as broad troughlike valleys with steep walls, deepened from 500 to 1000 feet or more beneath the side valleys that once joined them at even grade. The streams from the side valleys plunge down the rocky walls of the deepened main valley, forming fine waterfalls. Discordant side valleys of this kind are called hanging valleys.

Many hanging valleys are found in the Alps and in the mountains of Norway and Alaska; in the latter regions

movement of Alpine glaciers is on the average from 100 to 500 feet a year.

Glaciers press heavily on their beds, dragging rock waste beneath them and scouring the bed-rock clean and smooth. Loose grains and fragments of rock, dragged along by the ice, scratch and groove the smoothed rock surface. The rock waste thus scoured from the ice floor, as well as that torn from projecting ledges and that received in rock slides and avalanches from surmounting slopes, is dragged or carried along by the ice and laid down around its lower margin or at its end, or washed away by the stream that issues from beneath the ice. Great bowlders may be carried on the ice.



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Water received from side streams and supplied from melting ice gathers beneath a glacier and issues from an ice cave at its end. The water is usually whitened by fine "rock flour" ground beneath the ice.

172. The Work of Ancient Glaciers and Ice Sheets.—Certain parts of the world show the marks of ancient glacial action, although the climate there to-day does not allow snow to remain on the ground through the summer.

Ancient glaciers occupied certain valleys in the Rocky mountains of Colorado and in the Sierra Nevada of California. Great glaciers descending from the high Sierra into the

desert lowland in eastern California built strong moraines forward from the mountain base at the mouth of the valley.

Compare the glacier that once occupied the valley in Figure 150 with the Rosegg glacier, Figure 148.

Around the border of the Alps the lower land near the outlet of the chief valleys is often inclosed for ten or twenty miles from the mountains by a belt of hilly morainic ridges. The ancient glaciers that descended southeast from Mt. Blanc to the river-made plain of the Po built a huge terminal moraine, whose ridges rise from 1000 to 1500 feet above the plain and inclose a great amphitheater.

FIG. 150. Glacial Moraines, Sierra Nevada, California

The most extensive ice sheets of the glacial period were those that spread outward from the highlands of Canada across the basins of the Great lakes upon the northern part of the United States, and from the highlands of Scandinavia across the Baltic upon northern Germany. (See Figure 144.)

The highlands of eastern Canada, — the Laurentian highlands, — whence the ice sheets moved out to the surrounding regions, show much bare rock, clean scoured or covered

by a thin, stony, infertile soil. The hollows between the rounded rocky hills were often deepened by the ice, so that they now hold lakes or swamps, large and small. Besides many such lakes in rock basins, others are held behind barriers of rock waste or drift that was left irregularly over the surface when the ice melted away.

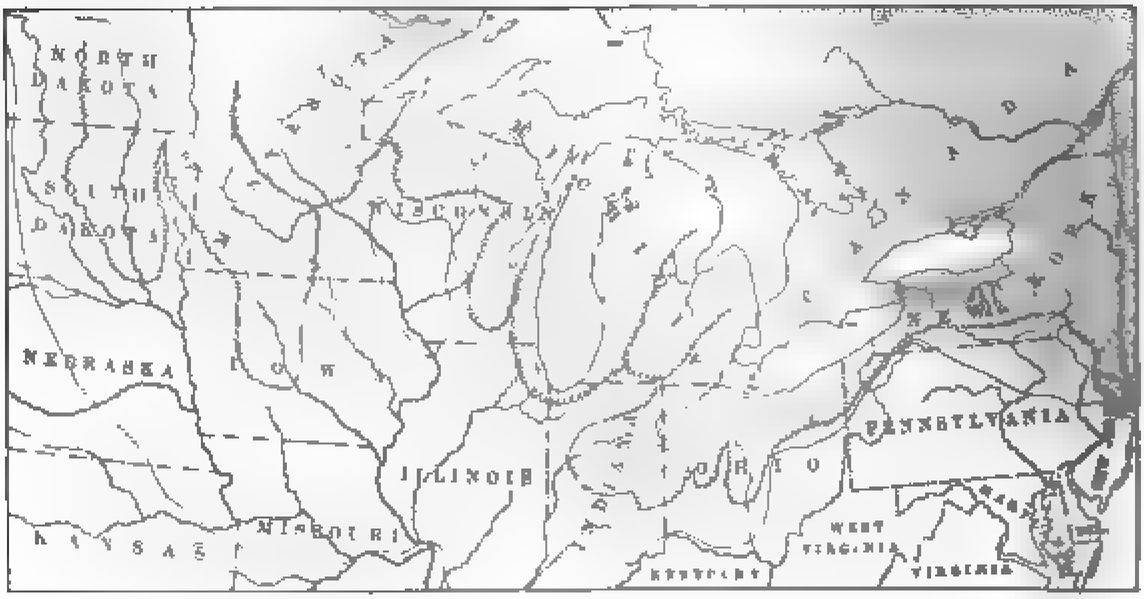

FIG. 151 Glaciated Area of the Northern United States

Much of the rock waste that has been swept from Canada by ice action is now found spread out in smooth plains, forming the fertile prairies south of the Great lakes. Rock waste that has thus been dragged along by ice action or washed along under or in front of the ice by streams is known by the general name of *glacial drift.*

The Scandinavian highlands and the lowlands of northern Germany exhibit the same relation to ancient glaciation that has just been described for the Laurentian highlands of Canada and the states bordering the Great lakes. The highlands are left with scanty soil and much bare rock;

the lowlands are sheeted over with drift, much of which is fertile farming country. The highlands remain in great part a wilderness, although scattered farms and small villages are found in the valleys. The lowland plain has a large agricultural population and many busy cities.

Among the most characteristic results of ancient glacial action are the rounded shapes of scoured ledges, Figure 152, and the irregular surface of the moraines, Figure 153.

FIG. 152. Ice-Worn Rocks, Coast of Maine

Terminal moraines of stones, gravel, and sand are strongly developed in the states south of the Great lakes. They form belts of hills commonly from three to ten miles wide; the hills are from fifty to two hundred feet high. The moraines are sometimes very uneven, with so many stony mounds and marshy hollows as to present a formidable barrier to travel. One may easily lose his way on such an undulating surface, where the hills are all much alike and where no conspicuous landmarks serve as guides.

Morainic hills are frequently dotted over with large rocks or bowlders, large and small, brought from some

Fig. 153. Glacial Moraines, North Dakota

more or less distant ledges by the ice; the bowlders are frequently unlike the rock on which the moraine lies.

Fig. 154. A Glacial Bowlder

Glacial bowlders are so plentiful in some parts of New England as to make the land there almost worthless.

PLATE XV. A Troughlike Glaciated Valley in the Western Alps

173. Drumlins. — In some districts the rock waste has been gathered beneath the ice sheet in arched, oval hills called *drumlins*, commonly half a mile or more long and from 100 to 200 feet high, easily recognized when once known. They may be compared to sand bars in rivers or to sand dunes under the wind.

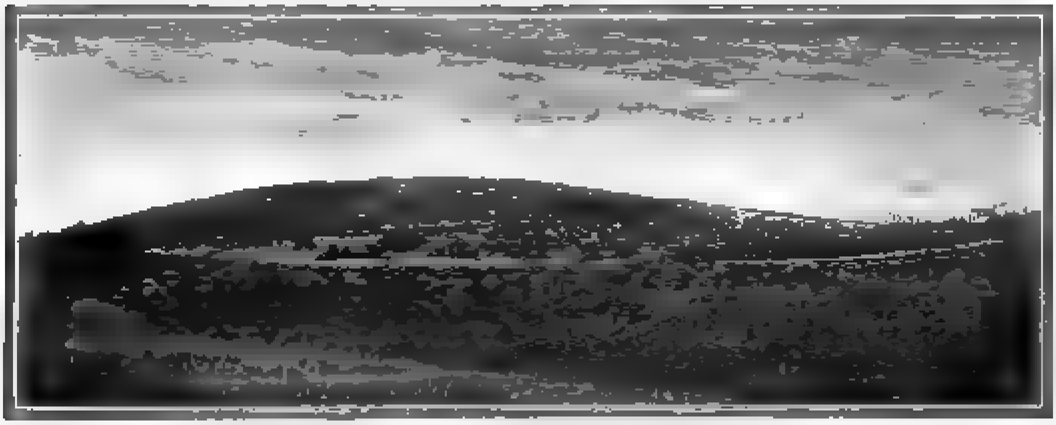

FIG. 155. A Drumlin, Massachusetts

174. Valleys, Lakes, and Waterfalls in Regions of Ancient Glaciers. — Some of the ancient glaciers of mountain regions were very massive, from 2000 to 5000 feet thick, and moved with relative rapidity down channels of rapid descent; here glacial erosion was most intense. The channels thus occupied are now seen as broad troughlike valleys with steep walls, deepened from 500 to 1000 feet or more beneath the side valleys that once joined them at even grade. The streams from the side valleys plunge down the rocky walls of the deepened main valley, forming fine waterfalls. Discordant side valleys of this kind are called hanging valleys.

Many hanging valleys are found in the Alps and in the mountains of Norway and Alaska; in the latter regions

the deepened main valley is usually occupied by an arm of the sea, called a fiord. (See page 320.)

The rivers of a region that has been overridden by an ice sheet are often greatly disordered. At one place a

FIG. 156. A Side Valley hanging over the Valley of the Ticino, Southern Alps

valley floor may be scoured out, producing a rock basin. Lakes occupying such basins have been mentioned as common in the rocky highlands of eastern Canada. At another place the irregular distribution of rock waste or drift may

turn a stream to a new course, where it is now seen cutting a steep-walled gorge with many rapids and falls. A lake is often formed upstream from the drift barrier.

The Adirondacks resemble the Black mountains of North Carolina in being dissected, subdued mountains, but the northern group possesses numerous lakes and gorges

FIG. 157. Lake in the Adirondacks, New York

("chasms") which are wanting in the southern group. These peculiarities result from glacial action, which the Adirondacks suffered in common with the other northern parts of the country, but which the southern mountains escaped.

When a river is displaced by barriers of glacial drift it must carve a new channel. Before the time of the ice action the river may have had a well-graded course; now its flow is interrupted by falls and rocky rapids. Hence the displaced streams of glaciated regions supply much water power for mills and factories.

Many rapids and falls of this kind occur in the streams of the northern United States and Canada. It must be concluded that the streams have not yet had time to establish graded courses since the ice melted away, and therefore that the ice sheet covered the country not long ago, as streams measure time, even though it was thousands of years ago, as time is counted by man.

The Merrimac is a famous river of this kind. Its falls at Manchester, Lowell, and Lawrence have determined the growth of great manufacturing cities. Rochester, Grand Rapids, Minneapolis, and many other important cities have grown up at the side of falls on rivers that have been turned from their former channels by glacial drift.

QUESTIONS

SEC. 159. What is meant by an ordinary climate? How are land forms carved in regions of ordinary climate? What are the conditions of a land surface in an arid climate? in a cold climate?

160. How are arid deserts related to the wind system? Consider their climate as to heat, cold, and dryness. Describe their surface as to vegetation and rock waste. What are the forms of deserts?

161. How is rainfall disposed of in a dry climate? Describe the streams of dry regions. What is a wady? What danger attends the use of a wady as a roadway? Describe the floods of the drier parts of the Rocky mountain region. Describe a flood at Denver. How may streams end in desert lowlands? What becomes of their load of waste? Where is their flow continued?

162, 163. Under what conditions are bad lands formed? Describe their form. Where do they occur? What becomes of the larger rivers of interior basins? What is the relation of inflow and evaporation in lakes without outlets? in lakes with outlets? Compare the lake area with the drainage area in the two cases. Why

are lakes without outlets usually salt? Describe Great Salt lake; the Dead sea. How is the form of interior basins changed? Describe the basin of the Dead sea; the basins of Persia; of central Asia.

164, 165. Compare wind action on plant-covered and on barren surfaces. Describe the action of whirlwinds in arid regions; of violent winds. How far is dust carried by the wind? Where do deposits of wind-borne dust occur? Describe sand dunes as to origin, height, form, movement. Describe the dunes of coasts.

166, 167. Describe the ancient shore lines of the Great Salt lake basin. What do they prove? Describe another similar example in Nevada. How do the two differ? What is the present condition of these two basins? What are salinas? Describe an example.

168, 169, 170. Where do ice sheets occur? When may a short-lived ice sheet be seen? Describe the movement of an ice sheet. What is known and what is supposed about the Antarctic ice cap? Describe the Greenland ice sheet. How are glaciers and icebergs related to this ice sheet? Where do the Eskimos of Greenland live?

171. Describe a glacier of the Alpine type. Where do such glaciers occur? How does a glacier move? What work does it perform? Describe a terminal moraine; a medial moraine. State the relation of vegetation to certain moraines.

172, 173. How has the occurrence of ancient glaciers been discovered? Where have such glaciers existed? What remains have they left? Where did the most extensive ancient ice sheets occur? What effect was produced by the North American ice sheet in eastern Canada? in the northeastern United States? What is glacial drift? Describe the effects of the ancient ice sheet of northwestern Europe. Describe the terminal moraines south of the Great lakes. What are glacial bowlders? Where are they plentiful? What are drumlins?

174. What are hanging valleys? Explain them. Where do they occur? What effect have ancient ice sheets had on drainage? Describe the drainage of the Laurentian highlands. Compare the Adirondacks and the Black mountains. What effect have displaced streams on industries? Name some examples.

CHAPTER X

SHORE LINES

175. The Border of the Lands — Next to the prospect gained from a lofty mountain, the view of the sea from the border of a highland is the most inspiring sight that the earth offers. To the traveler from an inland country it is as if the shore line marked the beginning of a new kind of world. There is the mystery of the distant horizon, far beyond which strange lands are hidden. There is the unceasing movement of the waves as they roll upon the beach, and of the tides as they slowly rise and fall; and the thought comes that thus the ocean has been rolling in waves, rising and falling in tides, ever since the lands and the waters were divided. With the sight of the vast ocean comes the thought of unending time.

While the surface of the land has been for ages attacked by rain and rivers, the border of the land has been attacked by the sea. The sun warms the air in the torrid zone, and thus the general circulation of the atmosphere is established. The winds beat on the ocean and form waves, and the waves run ashore and dash in surf upon the lands. The border of the land is worn back under so constant an attack, and the waste taken from it by the surf, as well as that washed into the sea

by rivers, is slowly carried away into deeper water by the waves, the currents, and the tides. In time the area of the land would be greatly reduced by the invasion of the sea, were it not for upheavals of the earth's crust by which the land is now and then, here and there, renewed.

FIG. 158. Sea Cliffs, Grand Manan, New Brunswick

176. The Work of the Sea on the Shore. — Where the border or coast of the land dips under the sea the water lies against it and marks the shore line. The waves and other agents work upon the shore and produce changes in its form. Hence the outline of any shore line depends, in the first place, on the form that the land had when its present attitude with respect to the sea was taken, and in the second place on the changes afterward made by the shore processes.

The agitation of sea water in waves is greatest at the sea surface and gradually decreases downward; but the large waves cause some slight disturbance even at depths of several hundred feet. The movement of water in waves is not steadily forward in the direction in which the waves travel, but repeatedly to and fro over small distances. The larger the waves and the shallower the water, the greater effect their agitation has on the bottom. Fragments of rock, large and small, are thus moved back and forth according to their size and to the strength of the waves. The fragments wear each other as well as the rocky ledges on which they are rolled and thrown. Thus the edge of the land is worn back by the sea, the shallower parts of the sea are slowly deepened, and the waste is slowly removed to deeper water offshore. Little work of this kind is done in calm or fair weather; but during storms the processes of grinding and transportation are actively at work, shaping the shore line and the shallow sea bottom.

The currents of shore waters are chiefly of tidal origin, but they are also sometimes parts of the general circulation of the ocean. Except in narrow channels, they are seldom strong enough, unaided, to move the waste that is strewn over the bottom; but when the waste is jostled by waves it slowly shifts along in the direction of the current.

If deep water reaches close to the land, the waves spend most of their strength close to the shore line, breaking violently on the headlands, whence they sweep loose material out to the deeper bottom; there it rests in comparative quiet. Bare rock is abundantly exposed on shores of this kind.

If the land descends slowly under the sea, the shore is fronted by shoal water; then much of the strength of the waves is spent on the shelving bottom before they reach the shore line. Rock waste is so slowly removed from a shore line of this kind that beaches of gravel and sand are commonly strewn along it; the waters offshore become somewhat turbid during storms with fine waste raised by strong waves from the shallow bottom.

177. Different Kinds of Shore Lines. — Two kinds of shore lines have already been described. In one the sea lies upon a smooth coastal plain that was once a sea bottom (page 144); in the other it lies on the flanks of a depressed mountain range (page 211). These two kinds are the types for many other examples.

Shore lines of the first kind are smooth and simple, and are bordered by shallow water. Shore lines of the second kind are irregular and are generally bordered by deep water. Those of the first kind border lowlands of weak strata; they have few good harbors and hence they do not offer good opportunity for traffic between land and sea. Those of the second kind generally have rocky headlands and islands inclosing protected bays, where harbors are numerous and trading settlements are favored.

178. Shore Lines of the First Kind. — The low plain of Buenos Aires dips gently beneath the sea, whose waters are shallow for many miles off the simple shore line. Large vessels cannot approach close to the land, except where an artificial harbor has been dredged out.

When storm winds blow from the sea they sweep the water upon the low coast and cause destructive **sea floods**; dikes are built along certain parts of the shore to keep the waters off.

The waves along the shallow shores of lowlands beat up the bottom sands and in time build **offshore sand reefs** inclosing narrow **lagoons**. The movement of currents along the sand reef forms a beach, straight or gently curved on its seaward side. On-shore winds blow sand from the beach and build sand hills or **dunes** of irregular form, sometimes fifty or one hundred feet high, on the reef. Flood and ebb tidal currents maintain passages, called **inlets**, through the reef, as at *D*, Figure 159.

Sediments are brought into the lagoons by streams from the land, and, with the aid of salt-water plants, the shallow lagoons are gradually filled and converted into **salt marshes** at high-tide level. Sand reefs, lagoons, and marshes are plentiful along the Atlantic and Gulf coast of the United States.

A sand reef is slowly worn back by the action of the surf on its beach. The dune sands are slowly blown back into the narrowing lagoon or upon the lagoon marsh. At last the lagoon and its marsh disappear, and the mainland is directly attacked and cut back in a low bluff. The retreat of the sand reefs may be more rapid on one stretch of the shore than on another; thus one part, *CA*, Figure 159, may have a bluff cut in the mainland, while another part, *AB*, is still fronted by reef and lagoon.

The coast of New Jersey is fronted by long sand reefs inclosing lagoons and tide marshes. Farther north at

Long Branch, a noted seaside resort, the land is already cut back in a low bluff. Severe storms cut away the base of the bluff, sometimes undermining the houses that are built too close to it.

The low coast of the middle Netherlands has retreated two miles or more in historic times. A belt of dunes, half a mile or more wide, lies inland from the smooth

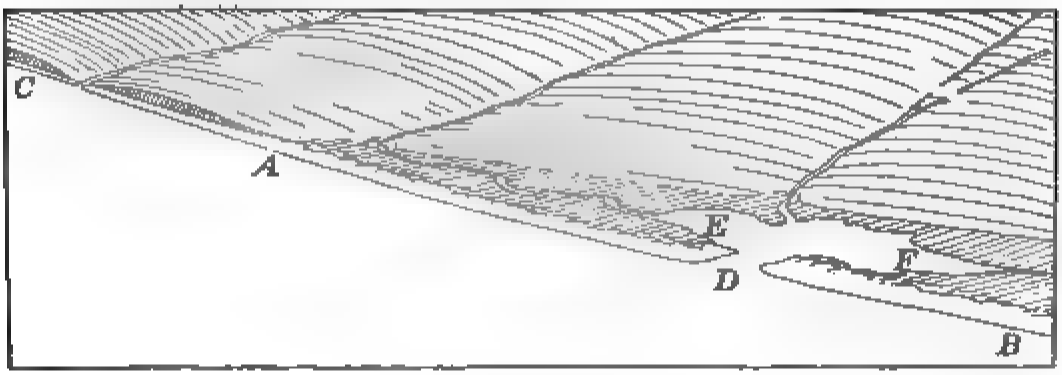

FIG. 159. Diagram of a Lowland Coast with Bluff and Sand Reef

Draw an outline map illustrating the features of Figure 159. Draw another map representing an earlier stage in the development of this shore line, when the whole length of shore was fronted by a reef and before any bluff had been cut. Draw a third outline showing a later stage, when the retreat is great enough to produce a bluff nearly all along the shore line, leaving only a small part fronted with sand reef and marsh-filled lagoon.

harborless beach. The chief ports are on the lower courses of rivers, whose channels are broadened by the flow and ebb of the tides.

The Romans built a castle back of the dunes, near the mouth of the Rhine. In 1520 the dunes had blown inland, grain by grain, and the sea had cut the shore back close to the castle. In 1694 the castle stood in the sea,

about half a mile from land. In 1752 it disappeared, destroyed by the waves.

In 1460 a church that had been built inside the dunes in the Dutch village of Scheveningen (near The Hague) was reached by the sea. A new church was then built about a mile inland, at the east end of the village. In 1574, the outer part of the village having been gradually consumed by the waves, new houses had been built east of the church, so that it stood in the middle of the village. In a later century the new church again stood close to the shore, the village having moved beyond it.

In southwestern France the west winds, sweeping in from the Bay of Biscay, have formed a belt of dunes two or three miles wide. Formerly the sand was drifted farther and farther inland with every westerly gale. Fields and villages were invaded and buried by the advancing drifts. Now most of the dunes have been planted with a kind of pine tree that thrives in a sandy soil; the wind is lifted from the sand by the trees, and the sand drifts have ceased advancing. The pine forests yield much resin.

179. Sea Cliffs. — As the margin of a plain is cut back by the sea, the shore bluff increases in length and height, until it may deserve the name of cliff. The cliff face weathers; fragments, large and small, fall from it to the beach below, where they are moved about and ground to pieces by the waves. The fine particles are drifted offshore to deeper water. Thus longer and longer stretches of the shore become harborless, and traffic between land and sea is greatly hampered.

In northwestern France the upland plain of Normandy fronts the sea in a vertical sea cliff, 200 or 300 feet high, with gently curving shore line for many miles. A large part of the plain must have been consumed by the sea in the development of the cliff.

FIG. 160. The Sea Cliffs of Normandy (looking southwest)

180. Shore Lines of the Second Kind. — These shore lines are more varied than those thus far described. When an uneven land surface is depressed and partly covered by the sea, numerous ridges and hills stand forth as promontories and continental islands, valleys are entered by arms of the sea, and protected harbors are plentiful. The irregular coast of Maine offers many illustrations of this kind. Its relief is of moderate measure.

The waves beat furiously on the exposed headlands of irregular coasts during storms. Angular rock fragments,

weathered from the rocky coast, are swept about by the dashing waves and are in time rounded to cobbles and pebbles, and worn down to sand. These fragments batter the shore and erode the margin of the land, gradually forming a cliff that rises above sea level and a bench that is partly bare at low tide.

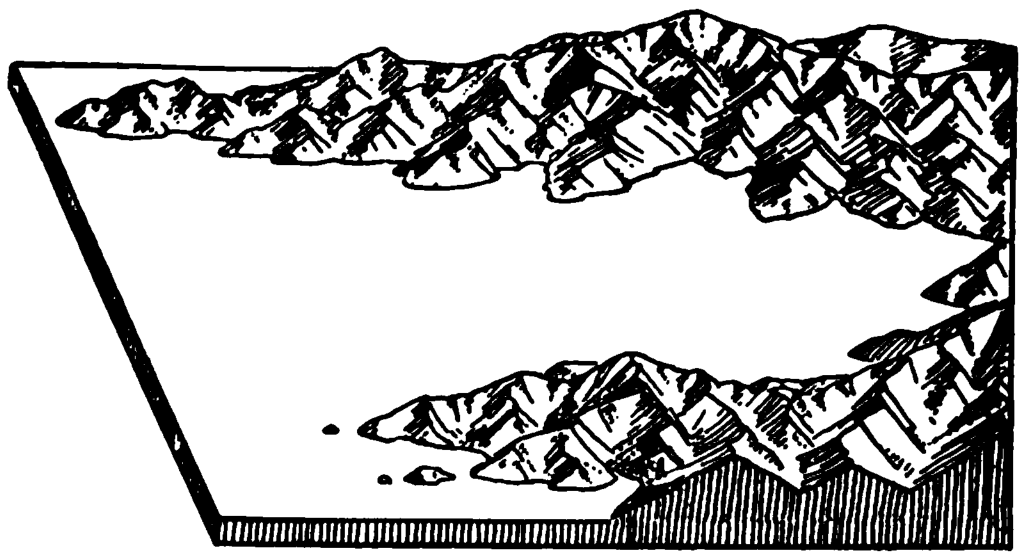

FIG. 161. Diagram of an Irregular Shore Line

Isolated rock columns or stacks stand for a time on the rock bench. At high tide the waves roll across the bench and sometimes excavate sea caves, fifty or more feet in length, at the base of the cliff. Fingal's cave, on the island of Staffa, west of Scotland, and many other less famous caves have thus been eroded by the waves.

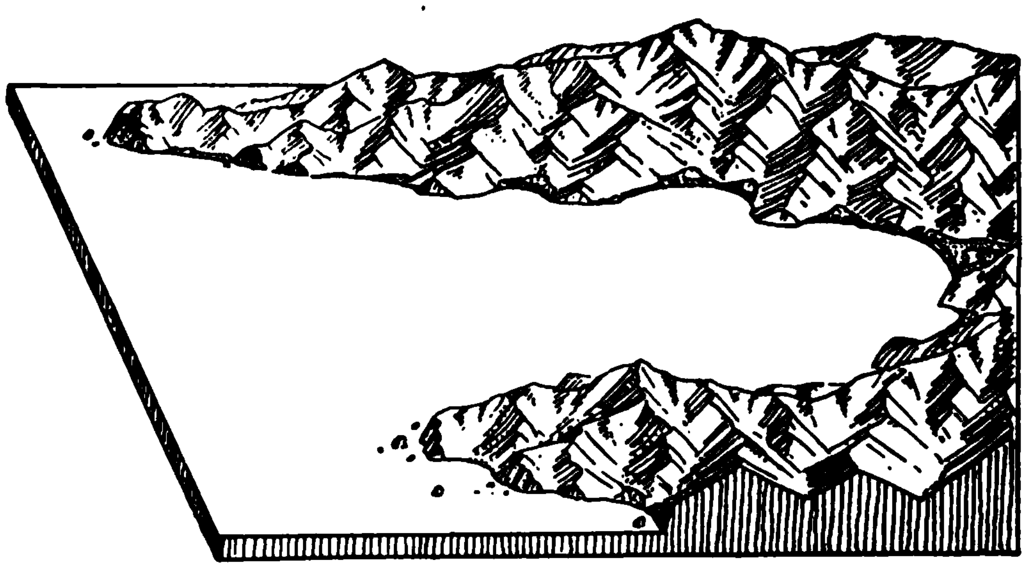

FIG. 162. Diagram of an Irregular Shore Line with Cliffed Headlands and Beached Bays

As the wave-cut bench broadens and the cliffs increase in height, some of the rock waste is swept alongshore from the headlands into the little coves and bays, forming

beaches on the more protected parts of the coast line. Such beaches present a smooth curve, concave to the sea; here the surf breaks in even rollers, quite unlike the dashing and fretting waves on the ragged headlands.

Draw maps of selected parts of the coast shown in Figures 161 and 162, on a somewhat larger scale than that of the figures, and thus illustrate the change from the original to the later outline.

The cobbles and pebbles thrown up on the beaches during storms may form a wall five or ten feet above high tide. A pond or swamp is often inclosed behind the wall beach in the valley that had previously opened into the bay. The New England coast has numerous beaches of this kind between its rocky headlands.

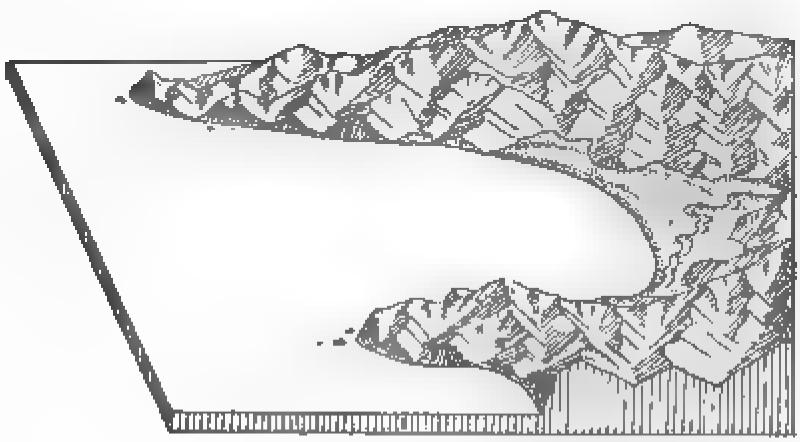

FIG. 163. Diagram of a Curved Shore Line

Compare the coast forms in Figures 161, 162, and 163. Where has the sea gained on the land? the land on the sea?

The promontory of Brittany in western France, beaten by heavy waves and swept by strong tides, is in about the stage of development represented by Figure 162. The headlands are dangerous on account of the rocky reefs that rise to half-tide height on the rock bench that fronts the ragged cliffs. The small bays are partly filled with curved beaches of cobbles, pebbles, and sand.

As time passes, headlands are cut farther back, so that the cliffs become higher and longer. The bays are more and more filled with beaches and cobbles, gravel and sand, and with deltas formed by streams entering the bay heads. Thus the outline of the shore becomes more regularly curved than it was at first, and convex lines of cliffs alternate with concave stretches of beach.

Fine examples of shores in this stage are found in parts of southwestern England. The cliffed headlands

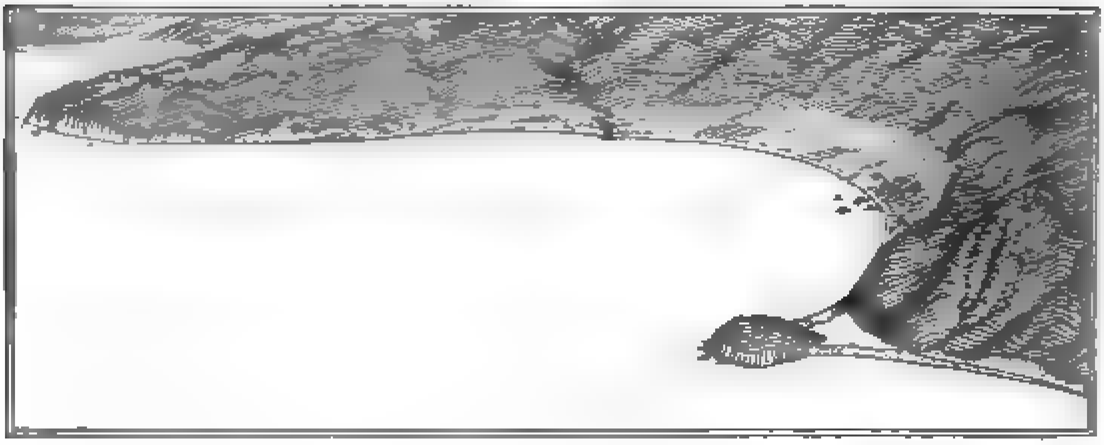

FIG. 164. A Cliffed Headland and a Land-Tied Island

are guarded by lighthouses; settlements are usually found in the river mouths of the beached bays. The coast of western Italy and the northern coast of California offer many examples of this kind.

181. Land-Tied and Sea-Cut Islands. — Irregular coasts, formed by the depression of a mountainous region, are often originally fronted by islands. Such islands not infrequently come to be attached to the mainland by the backward growth of sand reefs that are supplied with waste from the outer cliffs. Compare the two headlands of

Figure 164 in this respect. A land-tied island on the coast of Italy is shown in Plate XVI.

The fortified Rock of Gibraltar, belonging to Great Britain, was originally an island, but is now tied to the mainland of Spain by a broad sand reef. Part of the reef is "neutral ground," occupied by neither Spain nor Great Britain.

FIG. 165. Gibraltar

If the coast is of unequal strength along its front, the rate of sea cutting may vary from place to place, and thus parts of the coast may in time be cut off from the mainland and form islands, as in Figure 166. Many islands in the bay of Panama are thus formed. They are remnants

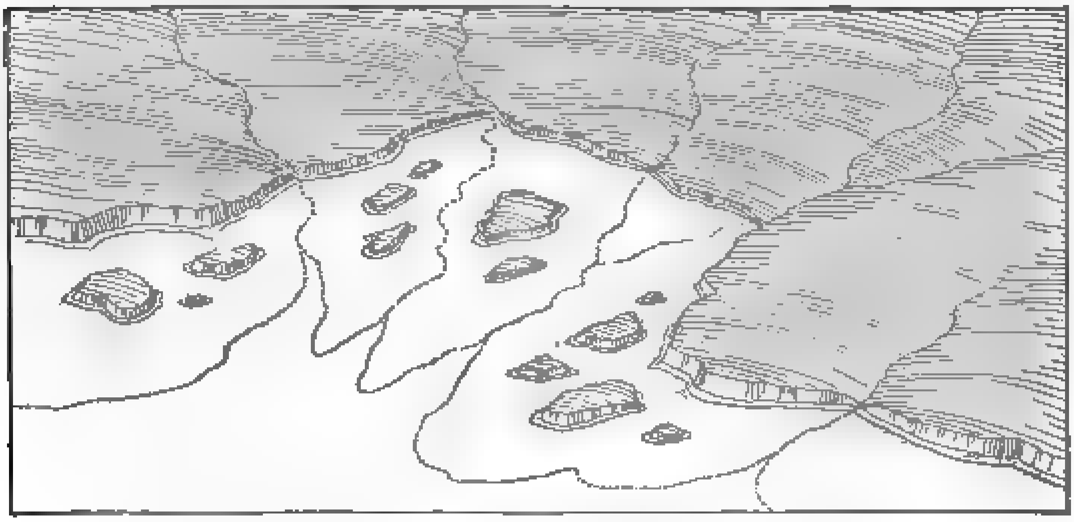
FIG. 166. Diagram of a Group of Sea-Cut Islands

of the mainland whose extent has been much reduced by the attack of the sea. The width of the isthmus of Panama has thus been lessened and the length of the proposed interoceanic canal across it has been correspondingly shortened.

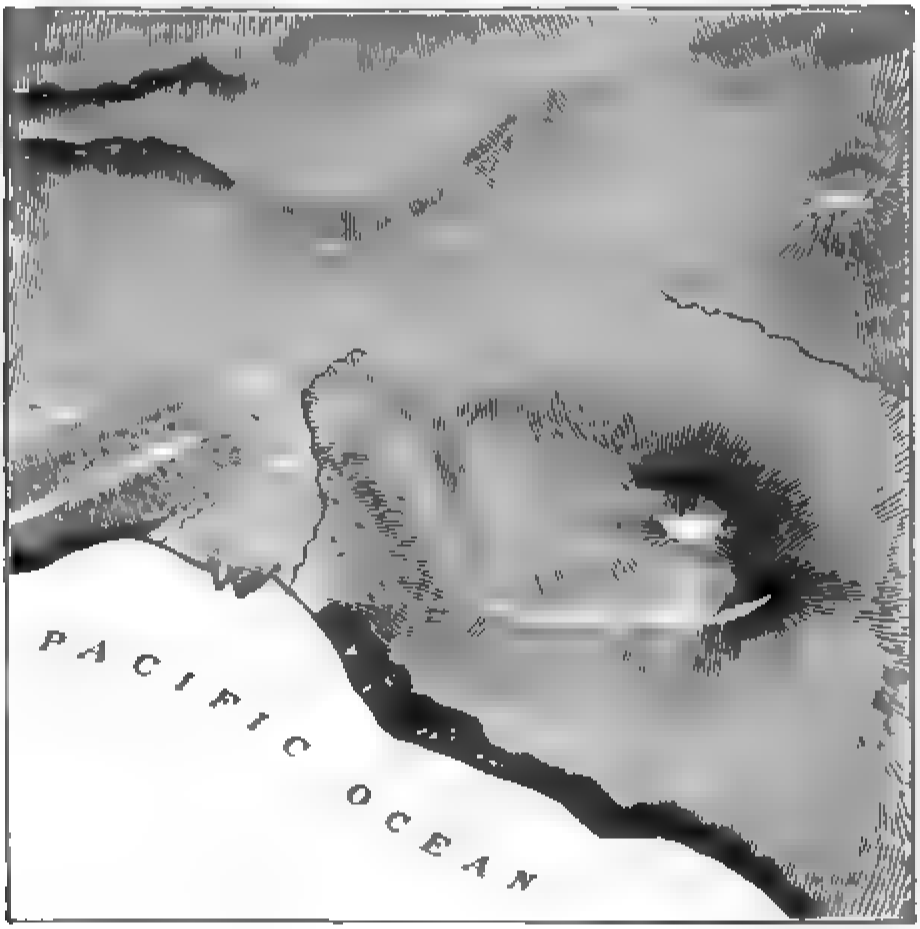

FIG. 167. A Cliffed Coast in Alaska

182. Cliffed Coasts. — Coasts that have been long exposed to strong waves and tides may have been cut so far back that no part of the original outline remains. In such cases a nearly continuous cliff, sometimes of great height, fronts the shore, as in Figure 167. Traffic between

land and sea is practically impossible on such a coast. A vessel wrecked on the ragged bench beneath the cliffs can receive little succor while stormy weather lasts.

The Orkney and Shetland islands, north of Scotland, have lost much of their former area by the attack of the sea. The headlands are cut off by lofty cliffs, some of which are nearly 1000 feet high. An isolated stack, known as the "Old Man of Hoy," rises 600 feet above the sea.

FIG. 168. The "Old Man of Hoy"

183. Elevated Shore Lines.—When the development of shore lines is interrupted by a change in the level of the land, the work of cliff cutting and bay filling must be begun again at a new level, in much the same way as before.

If the land rises, the former shore line may be found at a greater or less distance inland from the new shore line. This has already been referred to in the description of coastal plains.

An elevated shore line, marked chiefly by rocky cliffs and benches with occasional beaches, may be traced along a great part of the western coast of Scotland at a height of from twenty to twenty-five feet above the sea level of to-day. The narrow coastal plain that slopes forward from the old shore line to the new one is pictured in Figure 64. This elevated shore line forms a convenient bench along which roads may be laid near the base of the slopes that ascend to the highland summits. Old sea caves, roughly walled in, sometimes serve as stables for the seaside farmers.

A low bluff, seeming to be a former shore line, has been traced on the coastal plain of Virginia and North Carolina, a short distance inland from the present shore line. Lines of ancient sea cliffs at several different levels break the coastal slopes of Cuba and form steps in the broad plains of eastern Patagonia.

The western coast of Norway is bordered for much of its length by a belt of lowland and islands, sometimes as much as from three to ten miles wide, from whose inner margin an old sea cliff rises to the highlands (Figure 169). The lowland is a broad rock bench or platform, cut by the sea when the land stood about 300 feet lower than now. A large part of the population of western Norway dwells on this ancient sea floor.

The former sea cliff, at the inner margin of the platform, is from 500 to 1000 feet high. A number of rocky hills stand on the platform, representing unconsumed islands of the former shore.

The withdrawal of lake waters by a change of climate (page 288) has an effect on the condition of shore lines

similar to that produced by an elevation of the land with respect to the sea. The cliffs and beaches that contour around the slopes of the mountains of Utah, where the waves of Lake Bonneville once beat, in many ways resemble the elevated shore lines of western Scotland.

Well-defined ancient shore lines, consisting of cliffs and beaches, are found in the region of the Great lakes. The

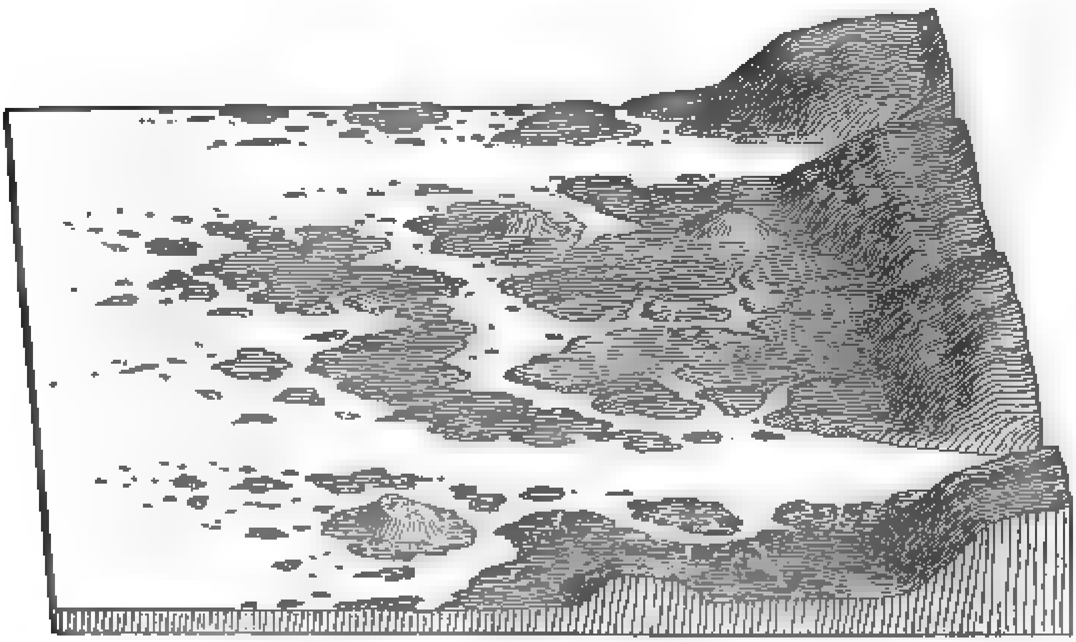

FIG. 169. The Coast Platform of Norway

shore lines are found to converge toward depressions in the height of land to the south of the lakes, and well-defined channels are there discovered. This indicates the former existence of lakes much larger and deeper than those of to-day, with outlets southwestward to the Mississippi system, instead of northeastward by the St. Lawrence.

These facts are explained by supposing that the melting ice sheet of the glacial period obstructed the St. Lawrence valley, so that the lake waters had to rise

high enough to overflow southwestward. Many of the beaches are so distinct that they are used as naturally graded roadways. The outlet of the expanded Lake Erie ran past the site of Fort Wayne, Indiana, to the Wabash river. The outlet of the expanded Lake Michigan led past the site of Chicago to the Illinois river; this channel is now followed by the artificial drainage canal by which some of the water of Lake Michigan is again led along the line of ancient outlet.

184. Fiords. — The valleys in the highlands of Norway have been deepened by the heavy and strong-moving glaciers that once filled them. Since the glaciers disappeared the sea has entered the deep channels that the ice scoured out, forming long, narrow, and deep embayments, called *fiords*, often deeper at the middle than near the mouth. Their depth has probably been increased by a depression of the region, by which the border of the ice-scoured lowland has been converted into a swarm of islands.

The rock walls of the fiords are so steep that few settlements can be made along them, except at their heads or where deltas are built by side streams that cascade from the hanging valleys (see page 299) of the highlands. Roads can seldom follow the shore lines; hence communication is chiefly by water.

An irregular coast of this kind has often favored the development of maritime arts. Its outlying islands tempt exploration; its protected bays afford safe harborage even for small boats. The people occupying the coastal lands become expert sailors and fishermen.

PLATE XVII. A Branch of Sogne Fiord, Norway

The numerous bays of southern Scandinavia were known as *viks* to the people who occupied them 1000 years ago, and the inhabitants were therefore called *vikings*, or bay people. They became bold marauders, invading the more southern coasts of western Europe, by whose people the

FIG. 170. A Delta in a Norwegian Fiord

vikings were called Northmen. Normandy is to this day named after these early sea kings. They were the first European people to venture far out upon the ocean, and thus almost 1000 years ago they discovered Greenland and other parts of the western world.

The west coast of Patagonia (southern Chile) resembles that of Norway in the possession of deep fiords among bold mountains. The Canoe Indians dwell here, — a

primitive people who find the steep slopes of the land so inhospitable that they live almost entirely in open canoes on the water. A small fire is kept burning on a few sods in the canoes, so that it may be carried from place to place. These Indians have no fixed habitations and make little use of the land, except when they build temporary shelters of tree branches, roughly thatched, in one cove or another where they stop for a time to gather shellfish.

The mountainous coast of Alaska is varied by numerous fiords, into some of which great glaciers descend from snowy ranges in the background. As in Norway, much of the coast is so steep as to be unfit for settlement. Hanging valleys frequently open on the walls of the fiords, 500 or more feet above sea level.

185. Delta Shore Lines. — Rivers tend to build their deltas forward, and thus oppose the destructive action of the sea. The Mississippi discharges a great quantity of land waste into the Gulf of Mexico. The waters of the gulf are relatively shallow, and the tides are weak. Here the outline of the delta seems to be governed entirely by the action of the great river (Figure 136).

The several distributaries of the Mississippi build low and slender banks of mud on each side of their channels faster than the waves can wear them away; hence the delta has several fingerlike projections into the sea. In order to increase the depth of water in one of the channels, or "passes," jetties (dikes of wood and stone) have been built forward beyond the end of the delta fingers, thus

increasing the current and forcing it to scour the channel to a depth sufficient for seagoing vessels to enter on their way to New Orleans.

The Rio Grande, a large river, but much smaller than the Mississippi, delivers land waste to the gulf in greater quantity than the waves and currents can altogether remove; hence its delta is built forward (Figure 171). But the waves are strong enough to smooth the outline of the delta; hence it has a gently convex curve without fingerlike projections. The Brazos and Colorado rivers, about midway between the Mississippi and the Rio Grande, also cause a slight forward bowing of the Texas coast.

FIG. 171 Deltas of the Texas Coast

186. Effect of Climate on Shore Lines. — Shore lines, like land forms, are affected by climate; not only by differences between regions of onshore and offshore winds, where waves and currents are stronger or weaker, but even more by differences of temperature.

In polar seas the land is often bordered by a fringe of ice called the ice foot. During the winter the ice foot usually remains attached to the land, unless broken by strong tides; in summer it may loosen and float away.

It is often used as a longshore roadway for sled travel by Eskimos and Arctic explorers.

In warm seas the shores that are not exposed to strong surf may be invaded by certain kinds of trees, forming a network so dense as to make landing difficult.

The mangrove is the most important tree of this kind. It grows freely in shallow sea water on low and muddy shores, and protects the land from the waves. Muddy sediments accumulate in the quiet water among the trees, and thus the land gains on the sea. Shores all overgrown with mangrove swamps are dismal as compared with the clean shell-strewn beaches of sand and pebbles beaten by trade-wind surf.

FIG. 172. Mangrove Tree

187. Coral Reefs. — The shallow waters of continental borders or mid-ocean islands in the warmer seas are commonly occupied by coral reefs, composed of the limy framework of coral animals. Living corals are found chiefly on the outer side of the reef, where they grow in the shallow water much in the same way that a thicket of small bushes grows on the land. They take

the limestone needed for their skeletons from solution in the sea water.

When reef-building corals first take possession of the shallow waters on a shoal or near a shore line, their growth extends upward from the shallow bottom and outward into the surf. Blocks and branches are detached from the bottom by severe storms and rolled about by the waves; the larger fragments are thrown together, forming a beach a little above sea level; the finer particles are carried toward deep water and strewn over the sloping bottom. The reef thus broadens, and if near the land, it forms a fringe close along the shore line. At this stage it is called a fringing reef.

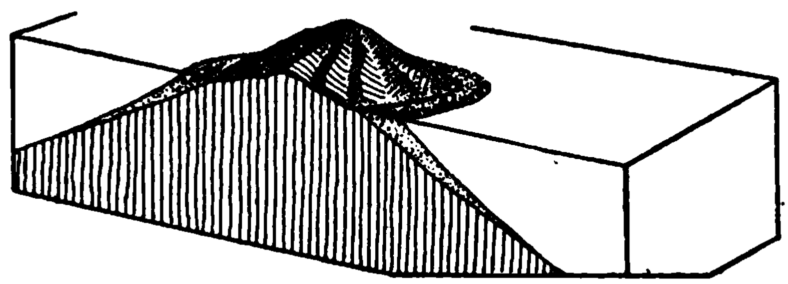

FIG. 173. A Fringing Reef

Strips of fringing reef are found on the equatorial coast of eastern Africa, along parts of the Brazilian coast, at various points on the coast of Cuba and elsewhere in the West Indies, and bordering many islands in the Pacific, as the Hawaiian and other groups. The Galapagos islands in the eastern Pacific, close to the equator, are free from reefs, because of the low temperature of the water brought there by the strong Peruvian current. (See Figure 112.)

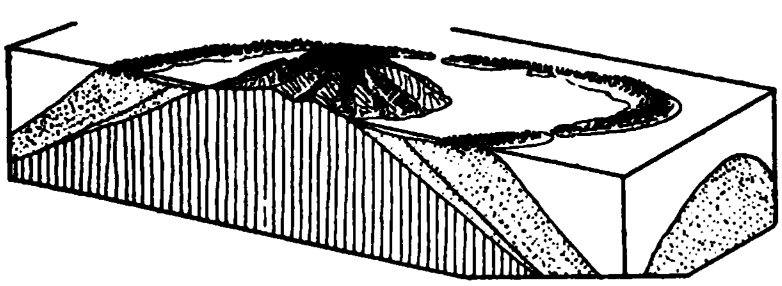

FIG. 174. A Barrier Reef

Draw maps of the islands and reefs shown in Figures 173 and 174. Compare the two.

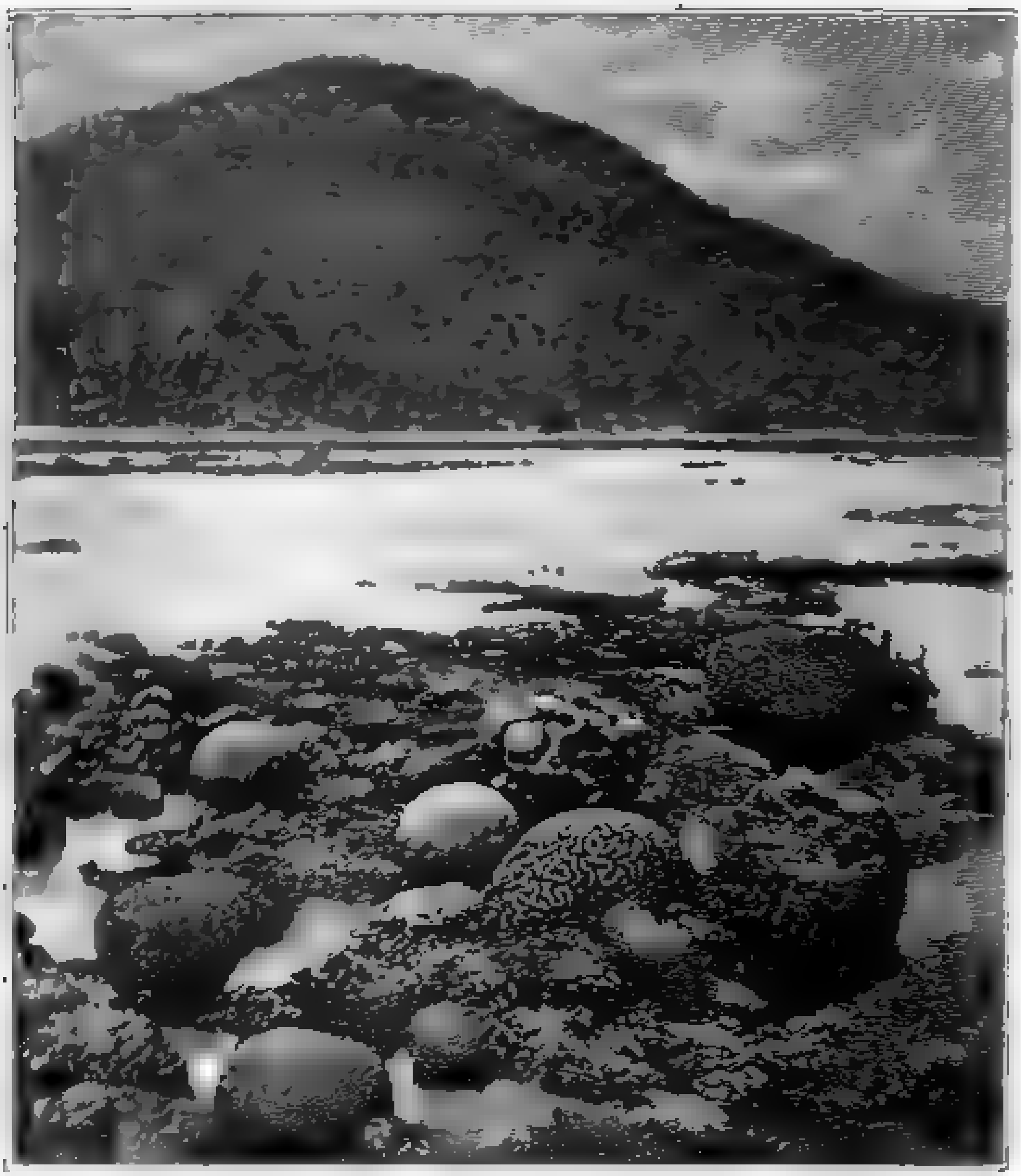

FIG. 175. Part of the Great Barrier Reef of Australia (as seen at low tide, looking toward the mainland)

188. Barrier Reefs. — A fringing reef broadens by the outward growth of the corals, and the submarine slope is built forward by the supply of coral fragments. At the same time water supplied by rain, by streams from the land,

and especially by the surf that rolls over the reef, slowly dissolves and washes away the inner part of the reef where living corals are few or wanting. Thus the reef may come to be separated from the land by a shallow lagoon a mile or more wide; and in this way a fringing reef may change to a barrier reef.

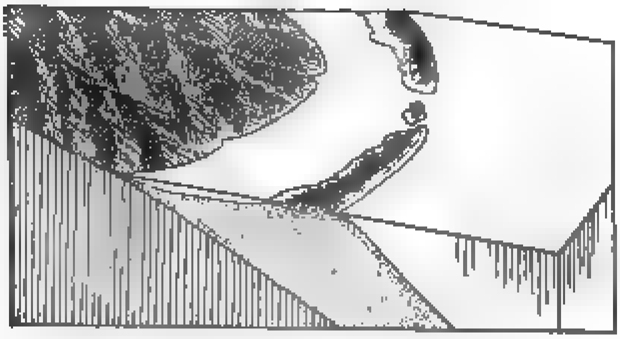

FIG. 176. Diagram of Part of a Barrier Reef

The Great Barrier reef stretches along the northeast coast of Australia for about 1000 miles, the largest reef in the world. It is usually from twenty to fifty miles from the mainland, mostly beneath sea level, interrupted by numerous inlets, and bearing a few low islets. The sea outside descends rapidly to great depths; the water inside is shallow (from ten to forty fathoms).

FIG. 177. Diagram of Part of an Elevated Reef with a New Fringing Reef

189. Effects of Elevation. — If a slow uplift occurs, corals will continue to grow on the outer face of the reef, but the body of the reef may be raised above sea level, forming a terracelike bench above the new shore line, outside of which new fringing reefs grow. Compare Figures 176 and 177.

An uplifted reef, forming a bench at a height of about thirty feet, with a breadth of a mile or less, borders much of the northern coast of Cuba. The sea has worn a low cliff in the front of the bench; from the cliff top one may look down upon the new fringing reef now growing in the sea.

The loose texture of uplifted reefs allows them to be worn down again with relative rapidity. While the uplifted reef is thus wasting away, the fringing reef may be growing outward vigorously and changing to a barrier reef. The uplifted reef will be in part dissolved by the solvent action of rain water; and it may, after elevation ceases, be reduced below sea level. A shallow body of water, or lagoon, will thus be formed within the new barrier reef.

190. Atolls. — If the central island within a barrier or fringing reef is worn away or is lost by slow submergence as the reef grows upward and outward, the reef may make an irregular ring around an oval lagoon and the ring may slowly increase in size by the outward growth of the reef, while the lagoon is deepened by the dissolving action of its waters.

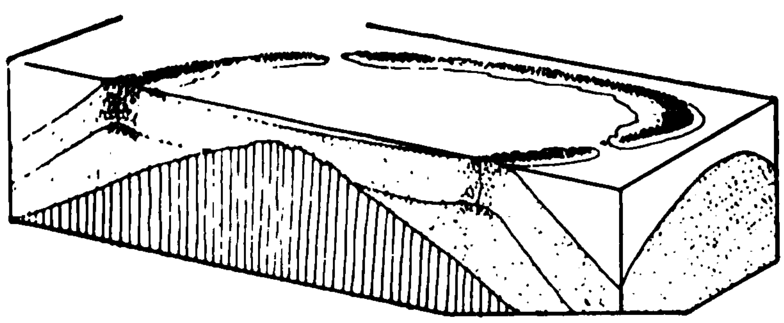

FIG. 178. Diagram of an Atoll

Such a ring island is called an atoll. Many islands of this kind are known in the Pacific ocean.

Compare the reefs shown in Figures 173, 174, and 178.

Although one of the most wonderful objects in nature, a lonely atoll affords little opportunity for human development. The natives of such islands lead easy and indolent lives, but their progress toward better conditions than those of savagery is hindered by the small variety in their surroundings and by their distance from lands of more varied form and products.

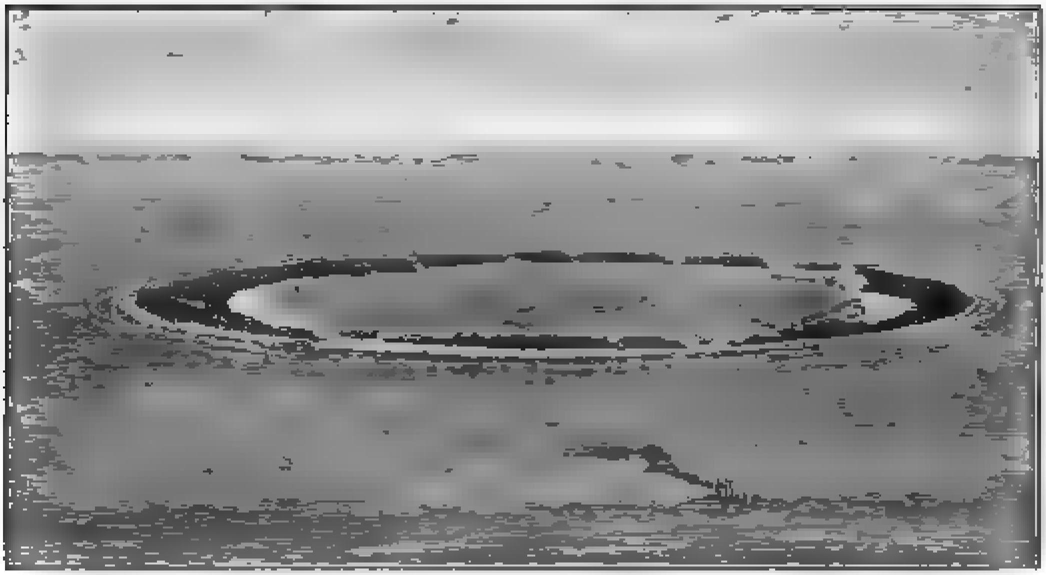

FIG. 179. An Atoll, or Coral Island

The small height of atolls subjects them to the danger of being overwhelmed by earthquake waves. Hurricanes sometimes come upon them, unobstructed from the open sea, sweeping violent surf far up the beaches; the storm winds break down the cocoanut palms on which the natives depend largely for food and for the materials for many of their simple arts. Atolls have no streams, but fresh water supplied by rains may be found not far below the surface. The thin soil has little variety of mineral

matter, but floating pumice (frothy lava) is often cast ashore from distant volcanic eruptions, and some of the islanders have learned to gather and pulverize it to use as a fertilizer for their little fields. Floating logs from other lands sometimes drift upon the atolls, and their roots occasionally carry stones of firmer texture than coral rock (for example, fragments of dense lava from a volcanic island); rude whetstones, pestles, and mortars are made from these chance supplies.

Although birds are plentiful, there were no mammals on coral islands until rats and mice came ashore from vessels; a few domestic quadrupeds have occasionally been imported by foreign residents.

QUESTIONS

SEC. 175. What is the origin of the forces by which the ocean works on the lands? How is the work done? What becomes of the material worn away? Why are the lands not completely worn away?

176, 177. Upon what two conditions does the outline of any shore line depend? Describe the movement of waves and their action on the lands. How are shore currents caused? How do waves aid the work of currents? Compare the work of the sea in deep and in shallow shore waters. Describe the shore line of a young coastal plain; of a depressed mountain range. Contrast them as to harbors, settlement, and trade.

178. Describe the shore of the coastal plain of Buenos Aires. What effects are here caused by storm winds? by waves? What are the origin and form of sand reefs? What are inlets? lagoons? salt marshes? How are the sand reefs and lagoons changed by the action of surf? Describe the coast of New Jersey; of the Netherlands; of southwestern France.

179. What is the origin of sea cliffs? How are they worn back? Describe the cliffed coast of northwestern France.

180. What are the features of a shore line of the second class? How and on what parts of these shores do waves form cliffs? stacks? caves? beaches? What are wall beaches and where are they common? Describe the coast of Brittany. Describe the shore forms of later development. Where are they found?

181, 182. What are land-tied islands? Describe an example. What are sea-cut islands? Describe some examples. Describe a cliffed coast. What is the relation of such a coast to human occupation? Describe an example. What is the "Old Man of Hoy"?

183. What changes in the shore line result from a change in the level of the land? Describe the elevated shore line of western Scotland; of North Carolina. Where are other examples found? Describe the western coast of Norway. Under what conditions were certain abandoned shore lines formed in Utah? around the Great lakes?

184. What are fiords? Explain their origin. Where do they occur? How do they affect settlements? How does an irregular shore line affect the maritime arts? Give an example from Scandinavia. Describe the Canoe Indians. What is the relation of hanging valleys to fiords?

185. How do rivers tend to oppose the action of the sea? Describe the delta of the Mississippi; of the Rio Grande.

186. How does climate affect shore lines? What is the ice foot? Describe a mangrove swamp. Where is such a swamp formed?

187, 188. What are coral reefs? Where are they found? (See Figure 112.) How are they formed? What is a fringing reef? Where are fringing reefs found? Why are no reefs found on the Galapagos islands? What is a barrier reef? How is it formed? Describe the Great Barrier reef of Australia.

189, 190. Describe an uplifted reef. What changes may such a reef undergo? What is an atoll? In what ways may atolls be formed? What opportunity do atolls afford for human development? To what danger are atolls exposed?

CHAPTER XI

THE DISTRIBUTION OF PLANTS, ANIMALS, AND MAN

191. Geographical Aid in Human Progress. — The study of physical geography, or physiography, gives a knowledge of the features of the earth, so that we may better understand the relation of man and nature. This relation is of great importance, because the progress of mankind from the savage toward the civilized state has been largely made by taking advantage of favorable geographical conditions and by learning to make greater and better use of the products and forces of the earth.

The winds blew over the lands and waters, carrying rain and causing waves and currents, for thousands of years while man was an ignorant savage. When he invented sailboats and windmills a new use was made of the winds, and man profited greatly by his inventions. Streams had been wearing down the falls and rapids in their valleys and spreading rock waste over their flood plains during all the long existence of the continents. When man cultivated food-bearing plants on the flood plains and built flour mills by the waterfalls, he gained much from making new and good use of these natural forms and forces.

The magnetic forces of the earth have always been capable of directing a compass needle, but they were not used

until man discovered how a balanced magnetized needle would behave. Coal and iron ore lay untouched in the earth's crust for millions of years; now the nations that make the fullest use of these invaluable resources have become the leaders of the world.

Reference has frequently been made on the earlier pages of this book to the effects of geographical surroundings on the growth and distribution of plants and animals and on man's way of living. The present chapter reviews these effects and gives new examples of them.

192. Life on the Earth. — The earth is known to have been occupied for ages past by various kinds of plants and animals, for their fossil remains are found in many rock layers of ancient origin. During all these ages living forms have tended to spread over as large a region as possible, just as they do now.

Barriers of different kinds limit the spreading of organic forms. Land plants and animals are stopped by the sea, unless they can travel by water or air. Sea animals are stopped by the lands. Those forms that need a warm climate do not spread into regions of cold climate. Grazing animals that need abundant grass are stopped by deserts and by forested mountains.

Plants growing from heavy seeds, like nuts, spread slowly from the parent plant. Plants growing from light seeds, especially from such as are carried by the wind, like the seeds of the dandelion, the thistle, and the fireweed, are very rapidly distributed. The dandelion is found on the northern lands all around the earth.

Certain kinds of sea animals, like mussels, barnacles, and corals, spend most of their life attached or rooted to the sea bottom, living on food that is brought to them by the moving waves and currents. This reminds one of the dependence of rooted land plants on the moving air for most of their sustenance. But the young forms of these fixed animals are free to float about, and are then carried far and wide by the currents of the sea, just as light seeds are carried by the winds.

Most animals can move from place to place. They have fins for swimming, legs for walking, or wings for flying. As they wander about in search of food, they come in time to be distributed over all parts of the earth accessible and favorable to them. This is as true for the ancient history of life on the earth as it is for the life of to-day.

Birds of strong flight are widely distributed. Walking birds and quadrupeds are more narrowly limited. The ostrich of Africa, the emu of Australia, and the rhea of South America are each confined to one of the southern continents. The albatross, a large sea bird, whose skill in flying without flapping its wings is very remarkable, is found all around the great southern oceans.

Occasional examples of some fifty kinds of North American birds are found in western Europe; but no stragglers from Europe are found in North America. This is because the prevailing westerly winds blow from North America toward Europe. The course of the winds is determined by the direction of the earth's rotation, and thus the rotation of the earth has an influence on animal distribution.

193. Geographical Factors in the Struggle for Existence. — The number of plants and animals in a given region is usually about as great as can be supported there. Where food is plenty the number of individuals is large; this is usually the case in the shallow borders of the seas and on the lands of the temperate and torrid zones. The luxuriant plant growth of the forests under the equatorial rains illustrates this rule. Where food is scarce, as in very dry and in very cold regions, the number of individuals is small; and some of the cold, snow-covered deserts are almost uninhabited, as in central Greenland.

Man frequently causes great changes in the numbers of plants and animals, as when he cuts down the trees of a forest and plants grain in the new-cleared fields, or when he kills the wild animals of a region and introduces domestic animals in their place. But apart from changes of this kind, the plants and animals of a region remain at about the same number for centuries.

It is, however, well known that every kind of plant and animal tends to increase in numbers, for the seeds of plants and the offspring of animals are always more numerous than the individuals that produce them. A single grain of corn may grow to a stalk bearing several ears, each of which may bear over a hundred grains. Many thousand eggs are contained in the roe of a single salmon. If all the young plants and animals reached maturity and produced other young forms in their turn, the number of individuals would increase enormously.

The reason that the number of plants and animals in a district does not greatly increase is that, in spite of

the production of numerous young individuals, many of them perish in the severe competition for an opportunity to live. Many seeds fail to germinate because they fall on unfit soil or because they are eaten by animals. Many young animals are devoured by other animals. As a rule, those individuals survive which have some advantage over their fellows and are therefore more fit to succeed in the "struggle for existence." The success of these individuals is often called the "survival of the fittest"; and the survivors are said to be chosen from those which perish by "natural selection."

The chances of survival in the struggle for existence are increased for those plants and animals which are best adapted to their geographical surroundings. Fish have gained a shape that enables them to move easily through the water: this is an advantage in getting their food and in escaping from pursuit. Many of the smaller animals of the open ocean move slowly; but they imitate the transparence of sea water and so make themselves almost invisible and more likely to escape their enemies.

As the earth is lighted from the sky, many animals whose backs are dark have lighter colors underneath, so as to counteract the effect of shade; they are thus less easily seen and so have a better chance of approach to their prey or of escape from their enemies. Animals inhabiting deserts are usually gray or tawny, imitating the color of the bare ground. In the snow-covered Arctic regions many animals are white.

Some animals gain protection by living in caverns or in the crevices of talus slopes; others burrow in fine

rock waste or soil. Name some animals of these kinds. Some animals choose steep cliffs and high peaks for their home, so that they shall not be easily pursued. Eagles build their nests on inaccessible pinnacles, such as those of the spurs that separate the huge side ravines of the canyon of the Colorado in Arizona. What can you tell about the home of the Rocky mountain sheep (the bighorn) and of the chamois of the Alps?

194. Variation of Plants and Animals. — All the many existing kinds of plant and animal life are the descendants of a smaller number of more ancient kinds. But when the ancient forms, preserved as fossils, are compared with living forms, it is found that they are not alike. Through the millions and millions of years during which the earth has been inhabited there have been slow variations in the kinds of plants and animals living on it, so that those now living differ from their remote ancestors. The forms of life to-day are, as a rule, very unlike those whose fossils are found in the oldest fossil-bearing rocks.

Among the many causes which have combined to produce variations in plants and animals, none have been more important than changes in their geographical surroundings. While part of a sea bottom is slowly raised to form a coastal plain, the kinds of animals that once occupied this part of the sea floor must seek some other home; at the same time the plants and animals of the neighboring older land have opportunity of taking possession of the young plain. As lofty mountains are slowly worn down to lowland peneplains, the forms of

life that once occupied the higher mountains must adapt themselves to their new surroundings or perish. During the slow change of climate which caused the gradual advance and retreat of the great ice sheets that once covered eastern Canada and the northeastern United States, plants and animals were first driven away from these regions and later allowed to return to them.

Changes of these kinds have repeatedly taken place in the earth's history, and it is probable that every one of them has caused some variation in the plants and animals of their regions. The plants and animals that we now find distributed over the world represent the present stage in the long series of varying forms.

195. Life in the Seas and on the Lands. — The different parts of the earth are so unlike that it is natural to find striking differences among the plants and animals which have become fitted to occupy unlike regions. No geographical contrast is greater than that between the sea floors covered by the oceans and the lands covered by the air. The kinds of plants and animals that have made their home on the lands have come to differ greatly from those that have for ages lived in the oceans. Hence continents and oceans must have existed for long ages because their plants and animals are now very unlike.

A remarkable difference between land and sea life results from the much greater density of water than of air. Even the largest sea plants do not need strong trunks, but are supported by the water. Many sea animals are no heavier than the water they live in; hence

they can float without exertion and all their strength can be given to swimming. The kinds of fish that sometimes rest on the water bottom lie upon it so lightly that they have no need of legs; all their members are fins. Many kinds of fish and other marine forms spend their lives in the open ocean without approaching the shores or the bottom.

Birds, on the other hand, are much heavier than the air through which they fly; hence much of their strength must be used to prevent falling. Even the best flyers spend some of their time on the ground or on trees. When they alight the air gives them so little support that they need legs on which to walk about.

It has been explained in earlier chapters that the deep ocean is monotonously cold, dark, and quiet, without changes of weather or seasons, and that the ocean bottom is usually a gently undulating plain covered with ooze or mud for thousands of miles together. The lands, on the other hand, are the seat of varied conditions. They possess a great variety of form and material; they experience changes from day to night, from summer to winter; they suffer many changes of weather from warm to cold, from calm to stormy, from clear to cloudy, from dry to wet. The development of the higher forms of life, such as are commonly found on the lands, should be regarded as a consequence of the great variety of geographical conditions found there, in contrast to the monotony of the deep ocean, where the forms of life are of a much simpler order.

Nearly all the flowering plants live on the lands. Water plants, especially those of the sea, are of a simpler kind. No plants live on the dark ocean floor, for plants cannot

grow without sunlight. Many animals of the sea are attached, plantlike, to the bottom. Others move slowly, like starfish and shellfish; still others float with the drifting waters, having little movement of their own, like jellyfish. Only the more highly organized, like many of the fishes, move rapidly; but nearly all land animals move about actively, walking, running, or flying.

The larger and more important land animals (mammals and birds) are warm-blooded. Most sea animals are cold-blooded, like the lower animals of the land. The only warm-blooded animals of the sea (whales, porpoises, seals, etc.) are believed to be the descendants of ancient land ancestors, gradually modified for the marine life which they have adopted. The reason for this belief is that the sea mammals still resemble in many ways the mammals of the lands. They bear their young alive and nourish them with milk from the breast; they must come to the surface of the sea to breathe, for unlike fish they have no gills by which they can make use of the air that is dissolved in sea water. They differ from land mammals only in ways that make them better suited for life in the sea; their legs have been modified into flippers for swimming; and those forms which, like the whales, live altogether in the sea no longer have fur, like the land animals of a cold climate, but are protected from the cold of sea water by a layer of fat or "blubber" under their skin.

Many land animals have developed organs for the production of sound, the most remarkable sounds being the song of birds and the speech of man. The animals of the sea are, with hardly an exception, silent.

The greater intelligence of many land animals than of sea animals should also be regarded as a result of the development of land animals amid a greater variety of geographical conditions than is found in the seas. The class of insects, almost limited to the lands, furnishes many examples of extraordinary instincts, such as those of bees and ants. Nest building by birds, house building by beavers, "homing" of pigeons, and trailing (by scent) of dogs are examples of highly developed instincts among land animals that have no parallel among the animals of the sea.

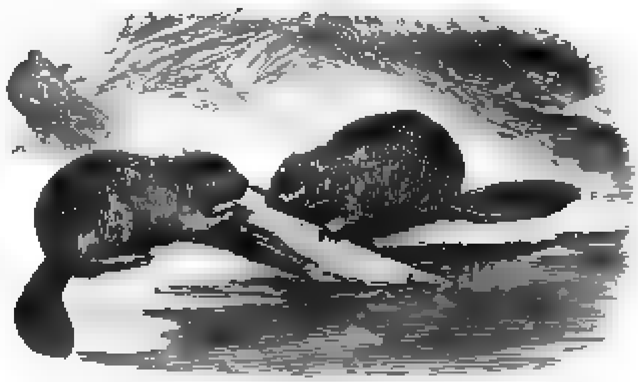

Fig. 180. Beavers

The wonderful intelligence of man has been developed on the lands, because only on the lands is to be found the great variety of form, climate, and products which can stimulate the development of high intelligence. It would have been as impossible for man to develop as an inhabitant of the dark and monotonous ocean floor as it has been for civilization to arise on the frozen and lonesome lands of the Antarctic regions.

196. Life on the Continents. — The arrangement of the continents has exerted a great influence on the distribution of land plants and animals. It has been stated that the northern continents are nearly united around the Arctic circle, and that three great extensions of this northern land belt stretch southward; Africa being most closely associated

with the northern lands of the Old World, South America being less closely associated with North America, while Australia is cut off from Asia by the sea. It is therefore natural to find many resemblances among plants and animals in high northern latitudes, and to find that differences among them become greater and greater as middle and low latitudes are passed and far southern latitudes are entered.

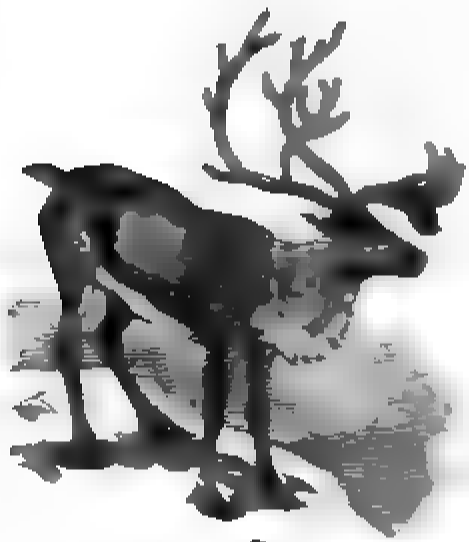
FIG. 181 Caribou

The lichens and mosses of the frozen northern lands are similar all around the Arctic circle. The animals of the same region include the polar bear, reindeer (called caribou in North America), lynx, musk ox, and Arctic hare, which are of the same kind on all the lands around the north frigid zone. The northern lands must therefore have once been connected, and their connection must have occurred at so late a period in the history of the earth that there has not since then been time enough for these Arctic animals to become unlike in their now somewhat disconnected homes.

In the lower latitudes of the northern hemisphere the plants and animals of the lands possess certain resemblances that prove their descent from a common ancestry, but they also show certain marked differences that prove the separation of the continents in these latitudes for a very long period of time.

The puma and jaguar of the New World are catlike animals that resemble in many ways the lion and leopard of the Old World. The resemblance is so strong that it must be believed they are descended from a common stock; hence in some former time the Old and New Worlds must have been connected in latitudes where the ancestors of these animals could pass from one region to the other; but this connection ceased so long ago that distinct differences have since then arisen between the two groups of catlike animals.

FIG. 182. Jaguar

The long separation of the Old and New Worlds is confirmed by finding certain plants and animals peculiar to each region. Horses, cattle, and other domestic animals, as well as tea, coffee, and wheat, originated in the Old World, while humming birds and rattlesnakes, as well as maize (corn), potatoes, and cactus plants, are peculiar to the New World.

The differences among the animals of the three southern continents are strongly marked. The giraffe, hippopotamus, and many kinds of antelopes are found only in Africa; but that continent shares with the adjacent lands of southern Asia the lion, elephant, rhinoceros, and the manlike apes.

South America stands more alone; here are found monkeys with prehensile tails, tapirs, llamas, sloths, and armadillos, none of which are found in the Old World.

In Australia, the most isolated of the southern continents, nearly all the quadrupeds belong to the peculiar

group of marsupials or pouched mammals, which carry the young in a pouch on the breast of the mother. The best known marsupial is the kangaroo. Australia contains also the lowest kind of quadruped, the water mole (or duckbill), which resembles birds in laying eggs from which its young are hatched.

It is not because Australia is unfitted for mammals that they are not native there. Rabbits have been carried from Europe to southern Australia, where they have become so numerous as to be a nuisance. Sheep are now raised there in great numbers, so that Australia has become an important wool-growing country. The absence of mammals in Australia must therefore be explained by the long separation of that land from the continents on which mammals were developed. In the same way, the absence of Australian forms in other parts of the world is not due to differences of food supply or of climate, but to the long separation of the island-continent from the other lands. The eucalyptus, a large Australian tree, thrives in the mild climate of California and southern Europe. So horses and cattle, brought from Europe to the New World, have become numerous on the prairies and plains of North America, and on the llanos and pampas of South America. Potatoes, native to America, have become an important

Fig. 183. Kangaroo

food supply in Europe. What can you tell about the English sparrow?

197. Races of Mankind. — It is not only in the distribution of the lower animals that the grouping of the continents has had a controlling influence. The several races of mankind, differing in language, religion, and form of government as well as in color, originally occupied regions that correspond in a general way to the grand divisions of the lands. Hence it may be believed that the separation of the continents by the oceans, aided by certain mountain and desert barriers, has been the chief cause of the division of mankind into races.

The greatest of the continents, Eurasia, contains two races. The European race, generally light colored but with some dark-skinned families, has its home in Europe, Africa north of the Sahara, and southwestern Asia. The leading nations of this race are the most advanced peoples of the world. They have developed liberal governments in which the rights of the people are considered, and have advanced greatly in the cultivation of the arts and sciences.

The Asian race is found chiefly in eastern, central, and northern Asia; it is often called the Yellow race. China contains the greatest number of this race, the Chinese being separated from the Hindus of India (a branch of the European race) by the lofty mountains of the Himalayan system. Although comparatively advanced in many arts, the Asians have acquired little knowledge of the sciences, and their governments are usually despotic. The Japanese are to-day their most advanced nation.

America is the home of the American or Red race; its native inhabitants are divided into many tribes, each led by a chief. Africa, south of the Sahara, is the home of the African or Black race, governed by despotic kings or chiefs. Australasia and the peninsulas and islands of southeastern Asia include certain black and brown races. Few nations among these races have made important advances toward civilization.

Within the last few centuries the means of travel over land and sea have greatly increased, and to-day the races of mankind are by no means limited to the continents named above as their homes. People of European ancestry now make the chief part of the population in North and South America, southern Africa, Australia, and New Zealand, as well as in Europe. The Chinese are not limited to China alone, but are found as merchants and laborers in the islands of southeastern Asia, Australia, and elsewhere. Many descendants of the African race are now living in North and South America.

It should be noticed that, while the people of the European race are now widely distributed over all parts of the world, and while Asians and Africans are found in large numbers in other lands than their homes, few of the less advanced races have entered Europe, the chief of these being members of the Asian race, the Turks in the southeast and the Finns and Lapps in the north.

198. Life on Islands. — Islands that rise from continental shelves are occupied by many plants and animals similar to those of the neighboring mainland. It is inferred

from this that the continental mass once stood higher than now and that the continental shelf was then a lowland on which the present islands rose as hills or mountains. The forms of life that were then widespread have become separated by the submergence of the lowlands and the division of the islands from the continent.

Various species of cassowaries, large ostrichlike birds unable to fly or swim, are found in Australia and on the hilly islands to the north, each land area having its own species. From this it is supposed that the ancestral family of all these species occupied the region when the continental mass stood higher and the mainland and islands were connected by the lowland now under water in the continental shelf. Since then it is believed that the region has been depressed and the lowland flooded by the sea, while the higher parts remain as islands separated from Australia and from each other. The differences between the various species of cassowaries must have arisen since their family was divided by the drowning of the lowlands.

FIG. 184. Cassowary

Many of the islands near Australia resemble that continent in possessing marsupials. The islands nearer Asia have no marsupials, but possess many mammals similar to those of the mainland to which they are related. A belt of deep water divides the two groups of islands.

Islands that rise from the deep ocean floor far from the continents have no large native animals, but are occupied by such forms of animals and plants as might have reached them through the air or the water from the nearest larger land.

The Azores, a group of mid-ocean volcanic islands in the North Atlantic, are so called from the hawks that were common there when the islands were discovered by voyagers from Europe. The Galapagos islands of similar origin in the Pacific west of Peru are named from the large tortoises that abound on them.

199. Climate as a Control of the Distribution of Plants and Animals. — Differences of temperature resulting from the globular form of the earth are of great importance in limiting the distribution of plants and animals. Plants like palm trees, that flourish in the torrid zone, spread into lands of higher latitudes on both sides of the equator until they reach regions where the summers are too cool for them to mature their fruit. Plants that occupy the temperate zones are limited to belts on whose polar side the summer is too brief and cool and on whose equatorial side the summer is too hot for their seeds to ripen. Thus in the central United States cotton is limited to the southern states, corn flourishes best near the middle of the country from the Ohio to the lower Missouri, and wheat is produced most abundantly in the northern states. In these northern latitudes there are great forests of pines and other cone-bearing trees. Still farther north, where the ground is frozen all the year round, except for a little

PLATE XVIII Forest in the Equatorial Rain Belt, Ceylon

melting during the short summer, trees are wanting and vegetation is reduced to stunted and herbaceous forms, with many mosses and lichens. (See Figure 112.)

The various kinds of animals are, like plants, limited to regions in which the summers are long and warm enough — but not too warm — for them to rear their young. But unlike plants, which live on mineral food derived from the soil and the air, animals subsist either on animal or vegetable food; and flesh-eating animals, like the lion, often devour plant-eating animals, like the antelope. Thus in the end all animals depend for food directly or indirectly on plants; hence the distribution of animals depends in part on the distribution of plants, and this in turn depends on climate.

Examples of the distribution of animals according to zones of temperature are found in the limitation of the caribou, moose, and elk to the northern parts of America; of the alligator, tapir, and sloth to low latitudes; and of the rhea to far southern America.

200. Climate as a Control over the Customs of Savage Tribes. — The customs of mankind are influenced in many ways by climate. Some of the climatic influences are direct, as with regard to clothing and shelter. Some influences are indirect, as with regard to food supply, which in turn is affected by the distribution of plants and animals. Climatic influences are less apparent on civilized people than on savage tribes; for the former have developed world-wide commerce, and thus gather supplies from all parts of the earth; while the latter know little or nothing

of regions away from their own home. Two examples are given in the following paragraphs.

The equatorial belt of Africa is in large part a densely forested wilderness, because of its plentiful rainfall. Tall trees spread their branches aloft, shading the ground all the year with their heavy foliage. Vines and creepers climb the trees and hang from bough to bough in great festoons, and the shady and damp ground is covered with a thick growth of bushes with stems and branches so closely interlaced that it is almost impossible to make one's way through them without cutting a passage. Even the wild animals of the forest go and come by paths that they keep open by frequent passing. Objects near at hand are hidden from sight; the explorer cannot tell what is ahead of him in the gloom of the forest until he is close upon it. Vegetation is here so luxuriant that it is a burden upon the people who live amid its abundant growth.

Some of the savages of this great forest are Dwarfs, from three to four and a half feet in height. They wear little clothing, for the air about them is always warm. They do not try to make clearings and to cultivate fields, but search out the more open parts of the forest and build their villages where the undergrowth is least dense. They have some trade with other tribes, but live chiefly by hunting wild game, which is plentiful. Although entirely ignorant of many simple arts practiced by people of more open countries, the Dwarfs are expert in all the ways of forest life. They can travel quickly through the woods, knowing all the paths and open places. They protect their villages from the attack of neighboring tribes by planting

sharpened stakes in the paths of approach. They dig pitfalls in the narrow forest paths, covering them with sticks and leaves, and in this way capture even the larger wild animals. They prepare a poison from certain plants and

FIG. 185. Dwarfs in the Equatorial Forest

tip their spears and arrows with it. In spite of their small size they are formidable enemies to invaders of their forest home.

The desolate shores of Greenland present conditions of an entirely different kind. Extreme cold prevails there during the long dark winter, and most of the land is covered all the year round with ice and snow,—a vast cold

desert. A narrow belt along the coast is free from snow in summer, and here live a few tribes of Eskimos; but the ground is so barren that they get little support from it. The only treelike plants are of stunted growth, seldom over two or three feet high. The herbage consists chiefly of mosses and lichens, which grow for a time in summer when the frozen ground is thawed for a few inches below the surface. A small supply of wood comes from the trunks of trees that are occasionally drifted by ocean currents to the Arctic shores from warmer regions; but there is so little of it that many articles which might be made of wood elsewhere are here made from the bones of sea animals.

FIG. 186. Eskimo hunting Walrus

The Eskimos wear heavy fur clothing. They travel in sleds drawn by dogs over the snow-covered land or the frozen sea. They make slender canoes, called kayaks, which they paddle very skillfully when hunting seals and walruses. Until visited by Europeans and Americans, the Eskimos were as ignorant of the rest of the world as were the African Dwarfs; yet so well have they learned to take every advantage of their frigid surroundings that they survive where men from a more civilized nation, unused to living in so barren a region, might perish.

These brief accounts of the Dwarfs and the Eskimos show very clearly that, as a rule, the climate and the other local

features of the regions in which they live exercise a strong control over their manner of living. The Eskimos know nothing of forests, thickets, and pitfalls. The Dwarfs know nothing of snow and ice, sleds, kayaks, and harpoons. But each of these groups of people has become well practiced in certain habits and customs that enable them to secure food, shelter, and reasonable safety of life; and these habits and customs are closely related to the surroundings in which they have been acquired. The further the world is examined, the more general this rule is found to be.

201. Effects of Change of Seasons on Plants and Animals. — In the torrid zone the chief seasonal contrasts of the year are between the dry (hot) and wet seasons. During the dry season vegetation withers, but with the coming of the wet season all forms of plant life grow actively. This is particularly marked on the desert borders of the subequatorial rain belt, where the ground may be bare and dusty in the dry season and covered with vegetation in the wet season, as on the llanos of Venezuela.

In higher latitudes the chief seasonal contrasts are between the cold and warm seasons, or winter and summer. In winter vegetable growth is almost or quite suspended, but with the approach of summer growth begins. Some trees, like the pines, bear the winter with little visible change. Others, like the oaks, drop their leaves in the autumn, and hence this season is often called *fall*. Trees of this kind pass the winter with bare branches. Still other plants are killed by the coming of cold weather, and only their seeds survive the winter; these are called *annuals*.

Animals also have many devices for surviving the winter. Some are hardy enough to bear all sorts of weather, and may be seen searching for food through winter cold as well as summer heat; wolves and foxes are of this kind. Others retreat into caverns and crevices and lie torpid during the cold months, coming forth lean and hungry in the spring; bears and snakes have this habit. Many insects are like the annual plants in being killed by cold weather, leaving their eggs to be hatched on the return of higher temperatures in the spring. Many birds escape winter weather by migrating to a warmer region in the autumn and returning poleward in the spring.

All these peculiar habits result from the oblique position of the earth's axis with respect to the plane of its orbit, by which the change of seasons is caused.

Changes in habit of life with changes of season are not limited to plants and the lower animals. Man also responds in many ways to seasonal changes from heat to cold, from dryness to rainfall. In continental interiors of temperate latitudes, where most of the rainfall is in summer, the wandering of nomadic tribes is largely controlled by search for pasture for their flocks; as on the plains or steppes north of the Caspian sea. Again, in Algeria, on the northern border of the Sahara, summer pasture is found chiefly on the mountain slopes; but when the winter rains begin (subtropical rains) the herdsmen drive their flocks down to the lower lands, that were dusty and barren deserts a few months before.

Planting and harvesting are characteristic occupations of the warmer months among the more advanced peoples

in all temperate climates; during the colder months agricultural labor is in less demand. In the north temperate zone there is the great advantage of an abundant land area with a winter that is cold enough to require the storage of food and a summer that is warm enough to provide the food to be stored. The leading nations of the world have arisen in this zone, and there can be little doubt that the habits of industry and thrift here made necessary, but not too difficult, by geographical conditions have been of great importance in bringing civilization out of savagery.

202. Plant and Animal Life on Lofty Mountains. — Climate varies not only from equator to pole, but also from lowlands to mountains. On account of the lower temperature and the heavier rainfall and snowfall of high mountains, their plants and animals are unlike those living on the surrounding lowlands. On lofty mountain flanks in the temperate zone, hardy cone-bearing trees usually succeed trees that need a milder climate. As the limit of tree growth, or the "tree line," is approached only stunted and deformed trees survive. Then comes a belt in which the slopes bear grass and Alpine flowers. (Alpine is used to refer not only to the European Alps, but also to the animals and plants of any lofty mountain.) Following this is the lower limit of summer snow banks, or the "snow line," above which some of the snow of one winter lasts over the following summer, thus excluding plant life. It is remarkable that many plants found near the snow line on mountains in the warmer zones are also found near sea level in the frigid zone, although they are wanting on the low ground between the two.

Many animals survive in mountains after disappearing from the surrounding lower ground. Various kinds of

Fig. 187 Stunted Trees at the Tree Line on the Slope of Pikes Peak

ibex (mountain goat) are found on the mountains of Eurasia, each range having its own peculiar species. All are derived from a common ancestry on the intermediate lower lands; but since they have been limited to mountain homes, the animals in each range have varied in their own way, independently of the others, and have thus come to be unlike. This is a remarkable illustration of the effect of mountains in keeping their inhabitants apart from the rest of the world; it may be compared with the effect of isolation on islands.

Fig. 188. Ibex

A species of butterfly living on the White mountain summits, in New Hampshire, is unlike the species of the surrounding lower ground, but resembles those of more northern lands. The top of Mt. Katahdin, an isolated mountain in northern Maine, possesses a similar butterfly, but it varies somewhat from the one on the White mountains, the variation having taken place since the butterflies of the two districts were isolated on their mountain homes.

203. The Effect of Mountains on their Human Inhabitants. — It has already been stated that the deep valleys of lofty mountains have often been used as retreats by the people of a nation that has been driven from the neighboring lower land by the invasion of a stronger nation. The following examples may be cited.

The Basques live in the northern valleys of the Pyrenees, near the angle of the Bay of Biscay. They are probably descendants of the Iberians, an ancient people who occupied a large part of Spain and France, from which they had been driven by invaders even before Cæsar made those countries subject to Rome, nearly 2000 years ago. The Basque language is the only surviving form of Iberian, and is entirely unlike other European languages.

The Svanetians occupy deep inner valleys in the Caucasus mountains, with difficulty accessible from the outer country. They are the descendants of an ancient people who occupied a much more extensive territory, from which they were driven back to the mountains many centuries ago. There ancient customs and a peculiar language are preserved; there the people still live entirely apart from

the ways of modern times. Although daring and patriotic, they are ignorant and superstitious. Their wretched houses are dark and dirty; their roads are only rough tracks. Arts and industries are of the simplest order; trade is only by barter.

The people who live in deep valleys among lofty mountains find life more difficult than do those who live on open plains. The difference between the two cases is in large part due to the action of gravity on the mountain sides. The peculiar dangers of avalanches and landslides are directly the result of gravity. The finer waste on the steep slopes is rapidly washed down by active rivulets. The stony soil that remains cannot be easily cultivated, and if it is spaded or plowed, much of it will be washed away by the next heavy rain.

The valley floors are narrow, giving little room for fields. The streams flow swiftly down their sloping channels; their torrential current is too strong to be navigated; their floods are frequent and destructive. It is difficult to pass from one valley over the dividing ridge to the next valley because of the labor of climbing up and down the slopes. Hence, although mountaineers are active and hardy, they are not, as a rule, great travelers or traders. The people of one valley know little of those a few score miles away, a distance that would be considered a trifle by a horseman on a plain. The people of neighboring valleys are often distinguished by slight differences in their common language.

During winter mountain valleys may receive a heavy snowfall. Then for a season the people and their flocks

are gathered in the lower villages, living on supplies stored up from the previous summer. In summer, when the snows are melted from the mountain sides, cattle, sheep, and goats are driven up from the valleys to pasture on the grassy slopes of the ridges. Hay is carried, often on the backs of the mountaineers, down to the villages for winter need.

204. Life in Deserts. — Climate exerts a powerful control over the distribution of life through differences of rainfall. This control is well illustrated by the conditions of those regions where rainfall is deficient. Plant and animal life is scanty in deserts because of the difficulty of securing food and water. The dryness of the soil is unfavorable to plant growth. Leaves are small or wanting, for thus the loss of water by evaporation from the leaf surfaces is diminished. Thorns are commonly developed, like so many signs, "keep off," as if to lessen the chance of injury to the plant in a region where living is so difficult that every aid must be summoned to protect life.

During long droughts an arid region may seem almost free from vegetation. If rain falls, small plants spring up everywhere, refreshing the surface with their green color, but soon withering away in the succeeding dry period. On the desert slopes of Peru, where droughts may last four or five years, plants soon spring up after a shower. These examples show that the plants of arid regions possess great vitality.

The larger plants of arid regions are thinly scattered, leaving much bare surface. There is no striving for space, such as commonly occurs in well-watered regions, where

plants of more active growth may crowd out the weaker forms. Dry regions seldom produce useful plants. Trees are small, and their wood is hard and knotted; they cast little shade on the dry, bare ground. The sagebrush, so abundant on the arid western plains of the United States, finds no use except as an inferior firewood.

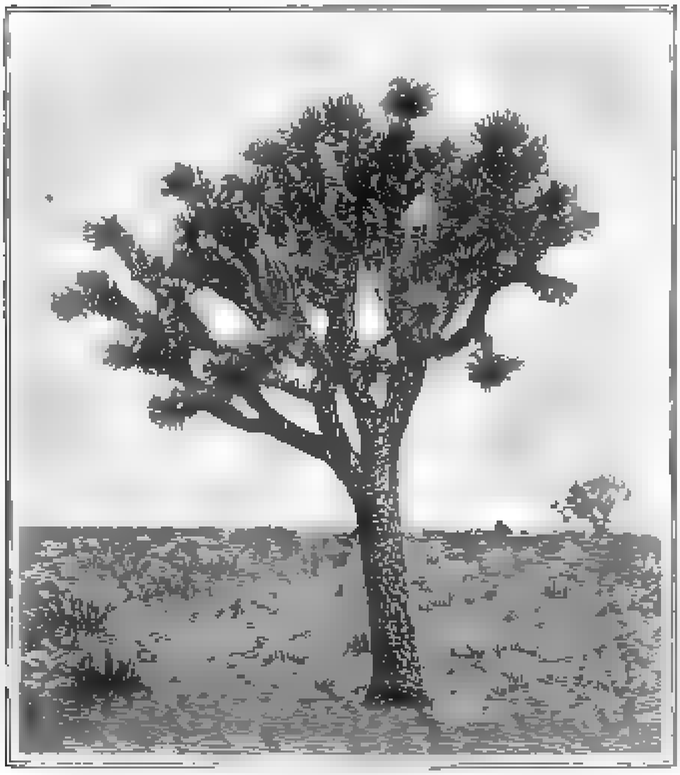

FIG 189. The Yucca, a Desert Tree

The animals of deserts are generally of dull or gray color, not easily seen on the barren surface. Many of them are fleet in movement, like the antelope, or of great endurance under a small supply of food and water, like the camel. Those which are sluggish are often venomous, like the tarantula, the scorpion, and the rattlesnake.

205. The People of Deserts. — The human inhabitants of arid deserts are few and miserable as compared with the more favored races of the world. Their food supply is scanty and of little variety. Their arts are primitive, for raw materials are of few kinds. They possess strength and endurance, without which life would be impossible under the difficulties around them; they have a keen intelligence

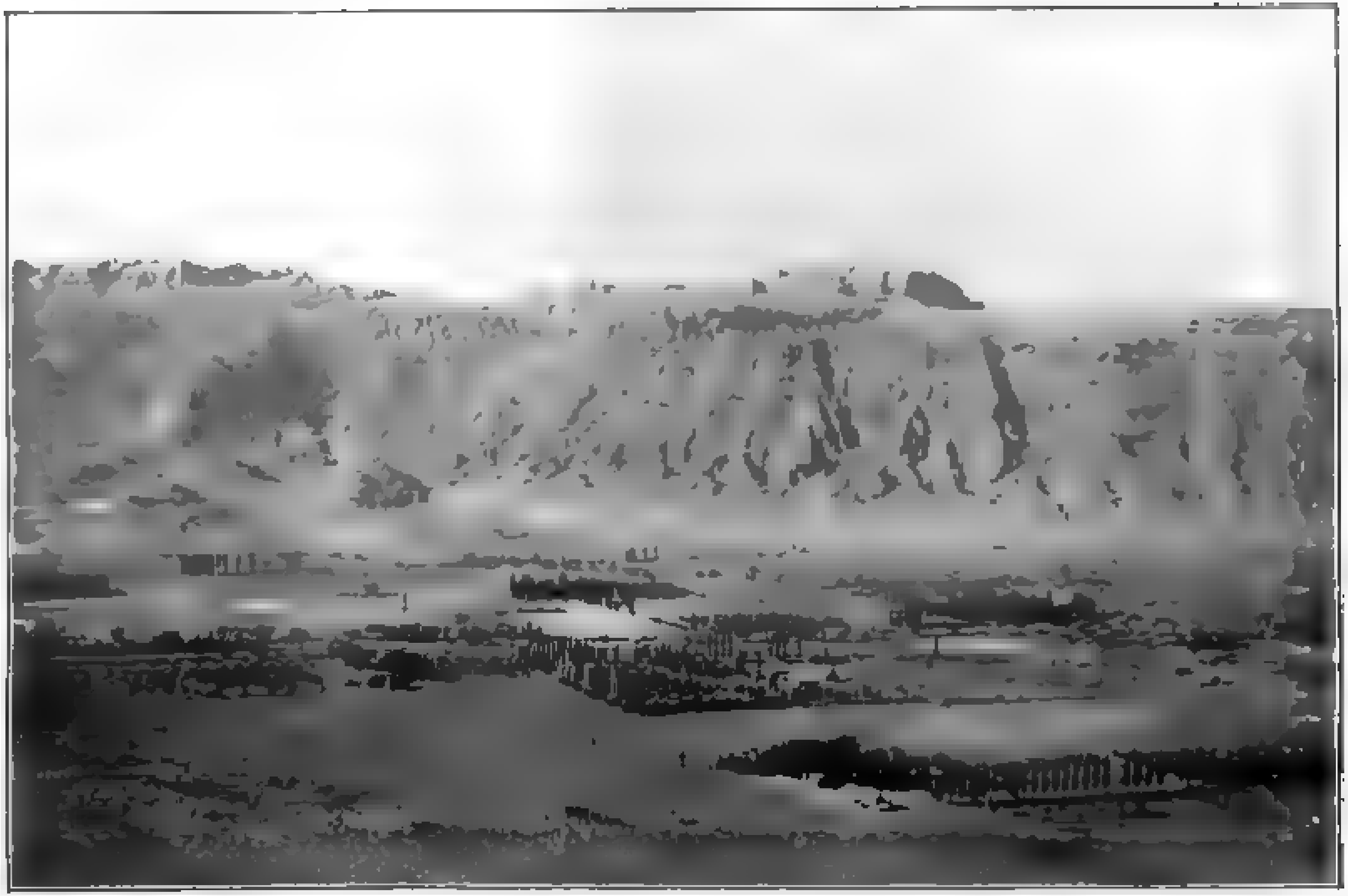

PLATE XIX. Moab, an Irrigated Settlement in Eastern Utah

for every advantage that their desert home affords, but they cannot rise above a low stage of development.

Many of the wandering tribes of the Sahara find the struggle for existence so severe that they and their animals are often on the verge of starvation. They must move from place to place to secure food; hence they do not build houses, but live in tents that can be easily carried about as they wander from one pasture ground to another. As a result of their wandering habits, they have come to be excellent horsemen and show great endurance in surviving the hardships that they must often suffer. But, on account of being nearly destitute, they have the habit of taking what they want from any passing travelers whom they can plunder. They have thus preserved into modern times a rude manner of life which must have been universal in the early history of mankind, but which has been given up in recent centuries by the people of more advanced nations, among whom theft is now punished as a crime.

The Papago Indians of the Sonoran region, south of the Gila river (southwestern United States, northwestern Mexico), move from place to place with the failing and flowing of springs. They are noted for strength, speed, endurance, and abstinence. The Seri Indians, living in the desert on the border of the Gulf of California, have no horses and are noted as runners.

206. Oases. — Fixed settlements in desert regions are controlled by the presence of water. They are commonly made where springs or streams flow upon the open country at the base of uplands and mountains; or near the ends of

such streams, where the water can be distributed in irrigating canals; or at points where ground water may be found in the nearly dry channels of withered streams. Such settlements are called *oases* in the Sahara, and the same name may be used elsewhere.

FIG. 190. El Kantara Oasis, Algerian Sahara

The barrenness of many deserts is due simply to their dryness and not to an unfavorable composition of rock or soil. Where springs or streams moisten the soil, grass and trees may grow naturally. If the surface can be irrigated, its productiveness may be increased so as to support permanent settlements.

The contrast between a habitable spot and the surrounding barrenness is so grateful that "an oasis in the desert" has come to serve as a poetic figure. But oases are only relatively delightful. Their water supply is often limited and impure; their products are few in variety and small

in quantity; their industries are primitive; their inhabitants have to suffer the disadvantages of isolation as completely as do the people of islands.

The oasis of Siwa, in the Sahara, 350 miles west of Cairo, "the first halting place on the great desert highroad to the west," is still little changed from its condition in ancient times. Seclusion seems to have bred mistrust, for strangers are looked on as intruders. They and their modern ways of doing things are unwelcome.

It sometimes happens that a river rising in well-watered regions flows across a desert on its way to the sea. If the river has developed an open and accessible valley, nearly all the population of the region is gathered on its flood plain.

The most famous river of this kind is the Nile, which flows 1000 miles through the desert without receiving a branch, except a few small wet-weather streams. Its flood plain, several hundred feet below the desert uplands that inclose it, is about 500 miles long and from 5 to 15 miles wide, broadening on the delta to over 100 miles. Here most of the millions of Egyptians dwell. Their resources are almost wholly agricultural and, as such, depend on the annual inundation of the Nile, caused by the northward movement of the belt of equatorial rains over the upper branches of the river in summer. The flood begins in June, usually rising twenty-five feet or more at Cairo in late summer or early autumn. For thousands of years the fertility of the flood plain has been maintained by the annual additions of river silt, estimated to amount to four and a half inches a century. Still better use of

natural conditions is about to be made by building a strong dam across the Nile on a reef of rocks that forms the first cataract, at Assouan, and thus storing in a reservoir a large volume of water for irrigation that would otherwise run to the sea unused.

207. Geographical Factors in the Life of Civilized Peoples. — It has already been shown that the simplest examples of the relations of man and nature are to be found in the life of savages, who know few arts and have little intercourse with other peoples and who are therefore directly dependent on the simplest home products. What can you say in this connection about the natives of coral islands?

Civilized nations offer much more complicated examples of these relations. Here the people are engaged in agriculture, manufactures, and commerce. Arts and trades are highly developed; the products of many parts of the world are gathered and skillfully manufactured into a great variety of articles for use at home and abroad. It might at first seem as if such a people had overcome geographical controls; but closer study will always show that they are influenced by them on all sides, and that their progress is less dependent on overcoming geographical obstacles than on taking advantage of geographical aids.

In savage tribes there are so few things to do that every man is well practiced in nearly all the duties of a man's life. In civilized nations man's work has become greatly diversified, and "a jack of all trades is master of none." Many occupations are immediately dependent on geographical factors, and the skill needed in them is so great that

few persons are successful in more than one. A miner, a farmer, a sailor, each knows his own work but would be at a loss in the work of his neighbors.

Some of the ways in which men gain a living require a very close acquaintance with geographical details. A river pilot must know all the bends and shoals in a river channel and must learn how they are changed by the action of the river in scouring away or building up the banks and in sweeping waste along the bed.

Certain peculiar occupations are dependent on a variety of geographical conditions. For example, in stormy weather the schooners that sail between our Atlantic ports sometimes anchor in shallow water near the shore. In very severe storms the cables may break and the anchors are then lost. But anchors are valuable; hence men, known as "anchor draggers," make a business of searching for them. They sail in pairs and drag a strong rope between their vessels over the sea bottom in frequented anchorage grounds, and they know their curious trade so well that they make a living by selling the anchors that they find. Can you give some other examples of this kind?

A member of an isolated savage tribe depends for food, clothing, weapons, and dwelling upon what he finds close to his home; if work is needed in building a hut, in securing food, in making clothing or weapons, it is usually done by each family separately. There are no mills where flour is ground wholesale; there are no factories where cloth is woven; there are no shops where household supplies can be bought.

In a civilized country a family may occupy a house which they had no share in building and which required for its construction the labor of many men in many trades, — masons, carpenters, plumbers, plasterers, and painters. The materials used in building the house may have been brought from hundreds of miles away. The stone for the foundation, the lime for mortar, the cement for the cellar floor, the clay for bricks in the chimney, the plaster for the walls are products of quarries and pits in different districts. The beams for the frame, the boards for the walls and floors, the shingles for the roof have probably come from different forests.

The furniture may be made from various kinds of wood, metal, and cloth, gathered from far and wide, put together in great factories, and distributed for sale. The carpets are very likely spun from wool from the pampas of South America. The iron in the kitchen utensils probably comes from iron ore in the old worn-down mountain region west of Lake Superior, smelted with coal from the dissected plateau of western Pennsylvania; the tin of tinware probably comes from the Malay peninsula southeast of Asia. The crockery may be from the lowland clay belt of the New Jersey coastal plain.

The daily food may include bread from flour ground by the water power of a displaced river in Minnesota from wheat grown in the rich drift soils of the northern prairies or in the deep-weathered soils of the lava plains of Washington, beef from the cattle ranches of the Great plains, tea from China, coffee from Brazil, sugar from Cuba, and salt from New York. The production of all these materials

depends on such geographical factors as rock, soil, and climate. Their preparation has required skilled labor of many kinds, in which natural forces are usually employed. Their transportation has been over lands and seas, along routes influenced by geographical conditions at every turn.

The family for whose comfort all these threads of activity meet in a single house may be that of a typesetter, skillful in his own work, but unprepared to take part in any one of the many arts and trades on which his home comforts depend. He would be almost helpless alone; but if he and every one else works faithfully and well, each one doing his chosen task to the best of his ability, the whole nation thrives. Yet civilized life is so complicated that, until attention is directed to its separate items, one might fail to notice how largely they are determined by geographical controls.

How many kinds of materials can you name that were used in the house you live in? How many of these materials can you trace back to their sources? From how many different states or countries did they come? What natural forces have been employed in preparing the materials for use? How have the materials been brought to their place of use? Similar questions may be asked concerning furniture, food, and clothing.

208. The Influence of Geographical Factors on History.— The progress of history has been repeatedly influenced by geographical factors. It is fortunate for the modern history of America that the Atlantic is narrower than the Pacific; it is chiefly for this reason that the New World has been peopled by emigrants from the leading races in the western part of Europe, instead of from the less advanced

peoples of eastern Asia. The eastern coast of North America has abundant harbors where the newcomers found safe refuge for their vessels. All the early settlements, many of which have now become important seaboard cities, were located on these protected embayments of the coast line; none of them were established on exposed headlands.

The boundaries of the several colonies founded by the immigrants were in most cases established with regard to the harbors on which the more important settlements had been made. The small size of several of the colonies, and of the states that now represent them, was determined by the occurrence of bays or rivers to the west, where other colonies were formed. Rhode Island, founded by settlements on the drowned valley known as Narragansett bay, was limited on the west by the colony which took possession of the lower Connecticut valley; and Connecticut was in turn limited by New York, whose inland growth from its excellent harbor was guided northward by the drowned valley of the Hudson. New Jersey was cut off from westward growth by Pennsylvania, whose chief city was established near the head of the drowned lower part of a valley, known as Delaware bay. The small state of Delaware was limited on the west by Maryland, founded on Chesapeake bay, the drowned lower valley of the Susquehanna; and Maryland was in turn limited by Virginia, to whose territory the Potomac embayment of the partly drowned coastal plain gave easy access west of Maryland. Farther south there are no important bays or rivers along the Atlantic coast with a north and south trend, and there are no more small states.

Mention some geographical factors on which the importance of New York city depends; of Chicago; of San Francisco. Mention some factors on which the small population of the Appalachian highlands and the great population of the prairie states depend.

Success in warfare has often been influenced directly or indirectly by geographical factors. The size of an army is largely the consequence of such factors as the area, form, climate, and fertility of the country to which it belongs; the strength of the less civilized nations has therefore often been measured by the number of their warriors. The character of soldiers is largely dependent on the habits of the community from which they are enlisted. Regiments of infantry recruited from among mountaineers have always been famed as fighting men, for they have learned endurance and courage from the severe conditions of life in their rugged homes. Regiments of cavalry recruited from dwellers on grassy plains are famous as "rough-riders," whether they are Russian Cossacks or American cowboys; their skill and endurance as horsemen are a natural result of habits developed in an open country of large distances, where riding is as appropriate a means of going about as walking is in a mountainous district.

What example can you give of a people whose home favored their becoming skillful sailors, and who thereby became invaders and conquerors of other lands? (See page 321.)

The fate of battle fields has been many a time determined by the arrangement of high and low ground; hence an intimate knowledge of land forms and of local geography is of great importance to military commanders. During the recent war in South Africa the Boers, having an

accurate acquaintance with their country, often occupied the crests of hills, and thus gained advantage over the British soldiers, who had to make attack while climbing up a slope from lower ground.

What can you learn about the Spartans at Thermopylæ? What can you tell of Braddock's defeat?

209. Geographical Factors favoring the Development of Great Britain. — The progress and prosperity of a nation are even more dependent in peace than in war on the advantage that its people have learned to take of their surroundings.

West of continental Europe, in the latitude of Labrador, there is an island whose climate is remarkably mild, because it is on the leeward side of an ocean across which the surface waters and the winds move obliquely poleward from warmer latitudes. The island is therefore fertile and has long been noted for its agricultural products. The narrow strait by which it is separated from the continent has served as a natural fortification against the armies of neighboring nations; nearly a thousand years have passed since the island has been successfully invaded. It has rich mines of coal and iron, and these natural products have been skillfully used in promoting manufactures of the most diversified kinds. It has excellent harbors, and many of its people have therefore been fishermen and sailors; its navigators have crossed the most distant oceans and have developed a world-wide commerce. As the population of the island increased under all these favoring conditions, many of its people emigrated to the new lands discovered by its explorers

and founded colonies in them; and to-day the sun never sets on the island's possessions. The empire thus established is the most widespread that the world has ever seen.

210. The United States. — A more modern instance of the dependence of prosperity on geographical elements is seen in the rapid growth, as a world power, of a young nation whose center of population now lies in a region where the winter is so severe that provision must be made for it, yet where the summer warms a fertile soil from which industry secures provision in plenty and to spare; where open plains and great rivers made it easy for new settlers to enter the country, and where the small relief of the surface favored the construction of the numerous railroads demanded by growing traffic, yet where the variety of form is sufficient to promote diversified industries; where the products of forest and mine are added to those of the farm, and where these excellent conditions are spread over so extensive an area that abundant opportunity is offered for a vast population.

Yet these favoring conditions have not been in themselves sufficient for the growth of a powerful nation. The aboriginal inhabitants of this great land were savages who did not know how to develop its riches. The entire territory remained a wilderness until it was entered by the descendants of a race that had, by long occupation of another highly favored region, gained a leading position among the peoples of the Old World.

But these members of the leading race of the Old World would not have left their homes for a new country, however

favorable its geographical features, if its government had been tyrannical and oppressive. It is therefore not local geographical factors alone that have so soon given this young nation a giant's strength, but three highly favoring conditions combined: a land well situated, of great extent, and rich in many forms of natural wealth; numerous immigrants from the leading race of the Old World; and a liberal form of government under which the highest opportunity is open to every citizen. Let us remember that "it is excellent to have a giant's strength, but tyrannous to use it like a giant."

QUESTIONS

SEC. 191. How have geographical conditions affected man's progress? Illustrate this by the use that has been made of the winds; of waterfalls; of flood plains; of terrestrial magnetism; of coal and iron. Give some examples of the effects of geographical conditions on the distribution of plants; of animals; on man's way of living.

192. How is it known that the earth has long been inhabited? What barriers prevent the spread of organic forms? Contrast the spreading of plants having heavy and light seeds. In what way do corals and mussels resemble certain land plants? How have free-moving animals been distributed? Contrast the distribution of walking and of flying birds. How is the rotation of the earth shown to be a factor in the distribution of certain birds?

193. How is the number of plants or animals in a region limited? How does man sometimes cause a change in these numbers? Why do plants and animals tend to increase in number? Why does their number not increase? Explain the phrases "struggle for existence"; "survival of the fittest"; "natural selection." Upon what does the chance of survival depend? Illustrate by examples from sea animals. What effects follow from the illumination of

the earth from the sky? Give some examples of protection gained by living in out-of-the-way places.

194. Compare ancient and modern plants and animals. How have variations in plants and animals been caused? Illustrate by changes in a coastal plain; in mountains; in climate.

195. Name one of the strongest contrasts of geographical conditions. What proof can be given of the great age of the continents and oceans? What consequences follow from the greater density of water than of air? Contrast the conditions of the sea bottom with those of the lands. State some results of these contrasted conditions. What can you tell about the warm-blooded animals of the sea? Why are they believed to be descended from land animals? Give examples of the remarkable instincts of certain land animals.

196. How are the several continents arranged? Over what region are similar land plants and animals found? Name some examples. Name some of the animals and plants of the lower northern latitudes in the Old and in the New Worlds. What is inferred from their differences? Name some of the animals of the three southern continents. Why are mammals not found in Australia? Name some animals and plants native to one part of the world and thriving in another part.

197. How has mankind been divided into races? In what ways do the races differ? Describe the races of Eurasia; of America; of Africa; of Australia. How are the races now distributed?

198. What forms of life are found on continental islands? What is inferred from this? How have these islands been separated from the mainland? Illustrate by the cassowaries; by mammals and marsupials on the islands between Asia and Australia. What forms are found on oceanic islands? What is the origin of the names Azores and Galapagos?

199. How does climate control the distribution of plants? Illustrate by the palm (see Figure 112), by cotton, corn, and wheat. What is the vegetation of the northern treeless belt? How does climate control the distribution of animals? Give examples. How does the

distribution of plants control that of animals? Give examples from North and South America.

200. Name some direct and some indirect effects of climate on man. Why are climatic influences more apparent on savage tribes than on civilized peoples? Describe the conditions prevailing in the forests of equatorial Africa. Describe the life of the Dwarfs of these forests. Explain the relation between their life and their environment. Do the same for Greenland and the Eskimos. What general truth do these examples illustrate?

201. Give an example of the effects of the change of seasons on plants in the torrid zone; in the north temperate zone. What are annual plants? Name several ways in which animals survive the winter. How does the oblique position of the earth's axis affect the life of plants and animals? How does change of season affect man's way of living? Give examples from the Caspian steppes; from Algeria. Of what advantage has winter been in the development of civilization?

202. How does climate vary on mountains? Describe the changes of vegetation seen on ascending a mountain. What is the tree line? the snow line? What are Alpine plants? In what lowland region are the plants of high mountains found? What may be learned from the distribution of the ibex? Give a similar example from the mountains of New England.

203. How have mountain valleys been used by defeated peoples? Give an example from the Pyrenees; from the Caucasus. Why is life more difficult in mountains than on plains? Name some of the customs of mountaineers.

204. Mention some of the features of desert vegetation. What is the effect of rain in a desert? Describe the conditions of growth of desert plants. What can you say of desert animals?

205. Describe the inhabitants of deserts; the conditions of life in the Sahara; the Indians of the Sonoran region.

206. What are oases? What controls their location? Why are deserts barren? Describe the oasis of Siwa. Describe the Nile

valley. To what are its floods due? Of what value are they? How is their value to be increased?

207. Where are the simplest examples of the relation of man and nature found? Why are civilized people less dependent than savages on natural conditions? How have civilized people been affected by geographical conditions? Give examples. What are anchor draggers? Show that savages are dependent on immediate surroundings and on individual work. Show that civilized people are often dependent on distant supplies and on the work of many men in many trades.

208. What geographical factors have affected the historical development of North America? How were the boundaries of the smaller northeastern states determined? Show that the character of soldiers and their success in warfare are dependent on geographical conditions.

209, 210. Describe the geographical factors that have favored the development of Great Britain. What favorable factors are found in the United States? What other factors have contributed to our national growth?

APPENDIX

REFERENCES FOR SUPPLEMENTARY READING

THE titles in the following list have been selected with especial reference to their accessibility in public libraries. Mention is made of the publications of the U. S. Geological Survey because of their great value to the geographer as well as of their wide distribution. Numbers preceding certain references indicate the page of this book to which the articles cited pertain.

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178. [illegible], N.M.; Abilene, Brownwood, Tex.

179. Mt. Trumbull, Kaibab, Echo Cliffs, Ariz.

CHAPTER VI. MOUNTAINS

191. [illegible], Alturas, Cal.

192. [illegible] Canyon, Huerfano Park, Col.

203. Asheville, Mt. Mitchell, Pisgah, N.C.

207. Atlanta, Ga. (Stone Mountain is a fine example of a monadnock on the uplands of Georgia.)

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208. Chesterfield, Granville, Mass.; Winsted, Derby, Bridgeport, Conn.
210. Harrisburg, Hummelstown, Lykens, Pa.
211. C. S. No. 710.

CHAPTER VII. VOLCANOES

222. Crater Lake (special sheet), Oregon.
230. Shasta, Cal.; San Francisco Mountain, Ariz.

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CHAPTER IX. DESERTS AND GLACIERS

281. Disaster, Granite Range, Long Valley, Nev.
299. Oconomowoc, Sun Prairie, Wis.
301. Elizabethtown, Mt. Marcy, N.Y.
302. Rochester, N.Y.; Minneapolis, Minn.

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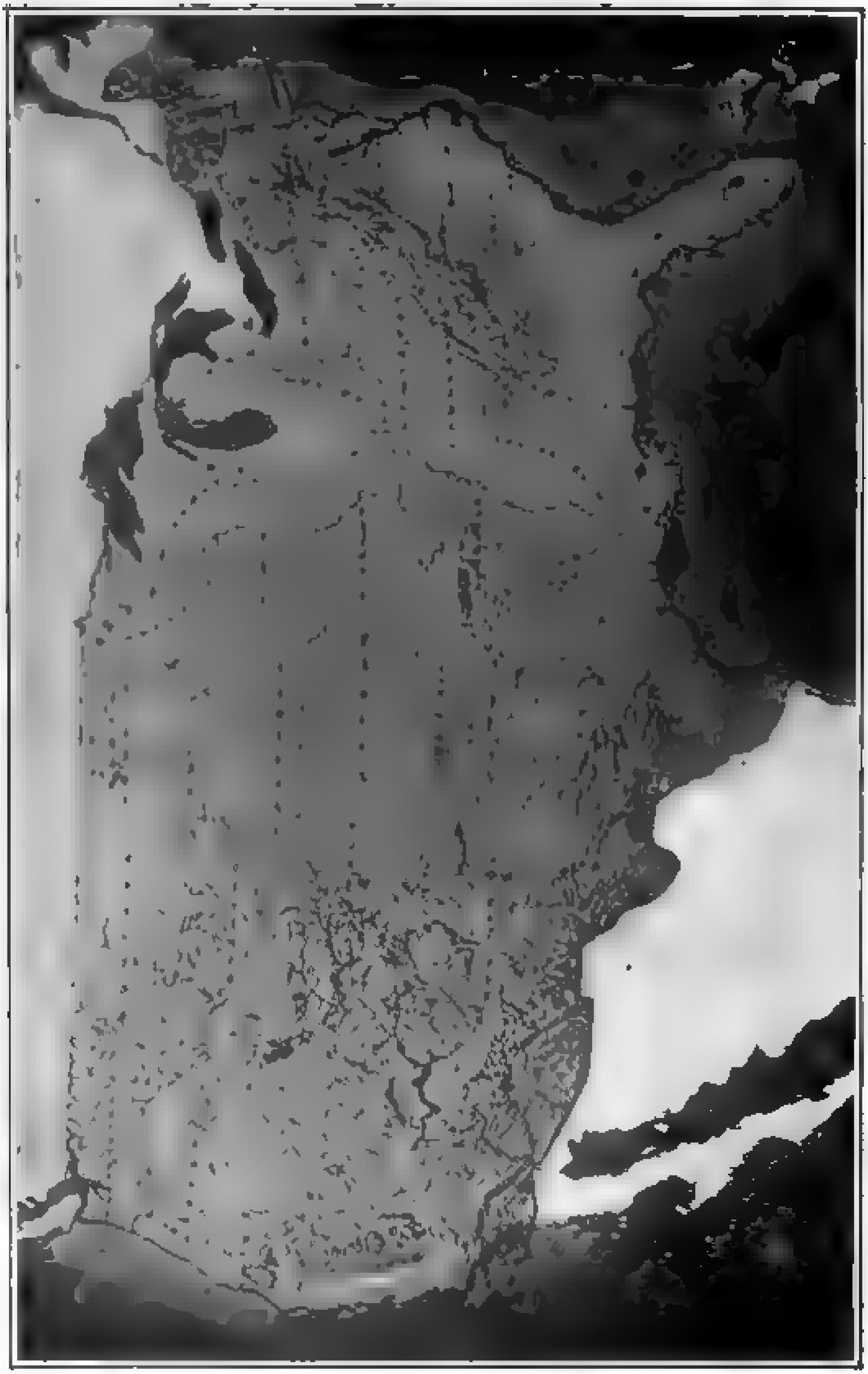


RELIEF MAP OF THE UNITED STATES.

From Model by Edwin E. Howell.

PLATE B.

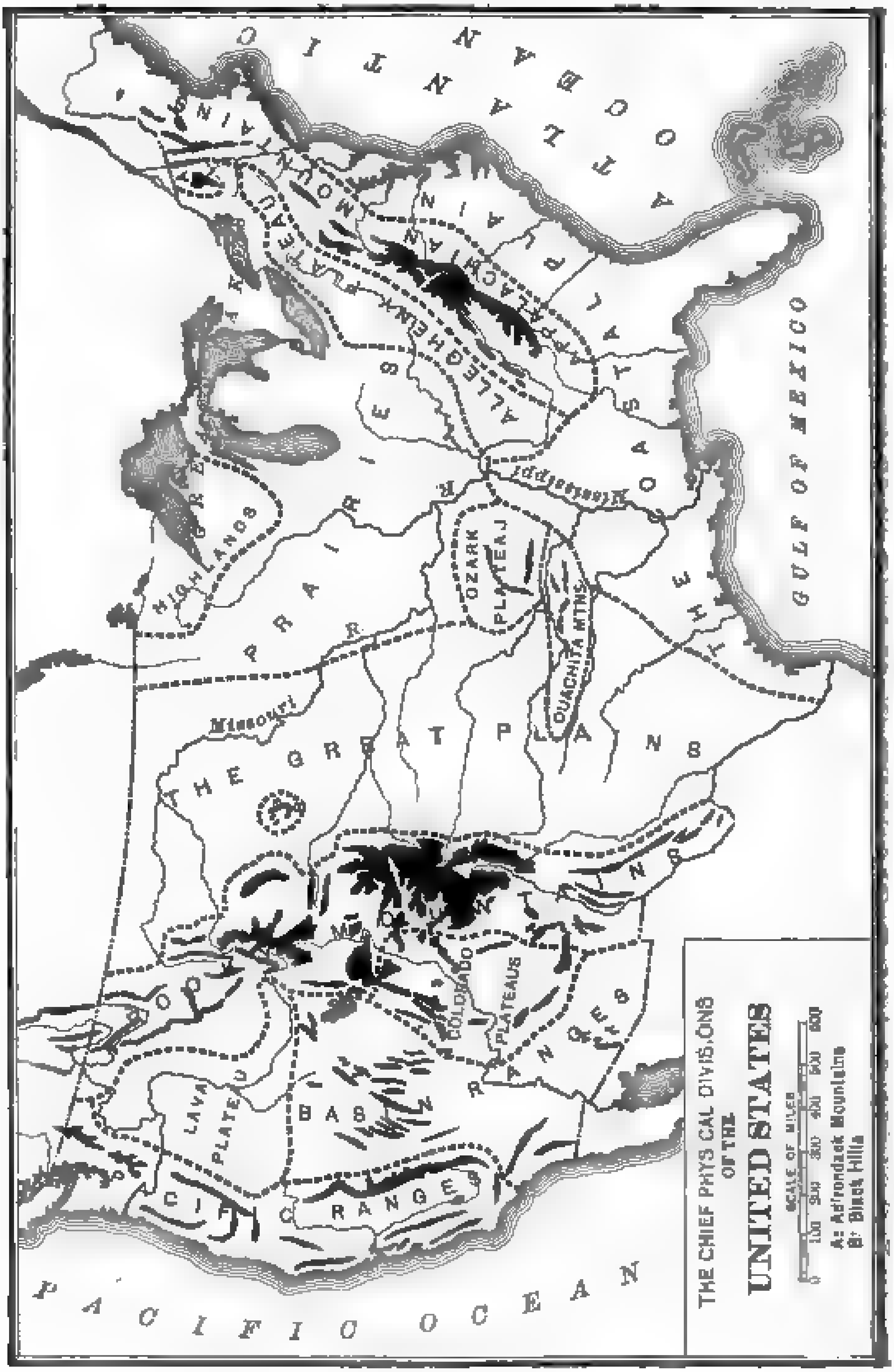
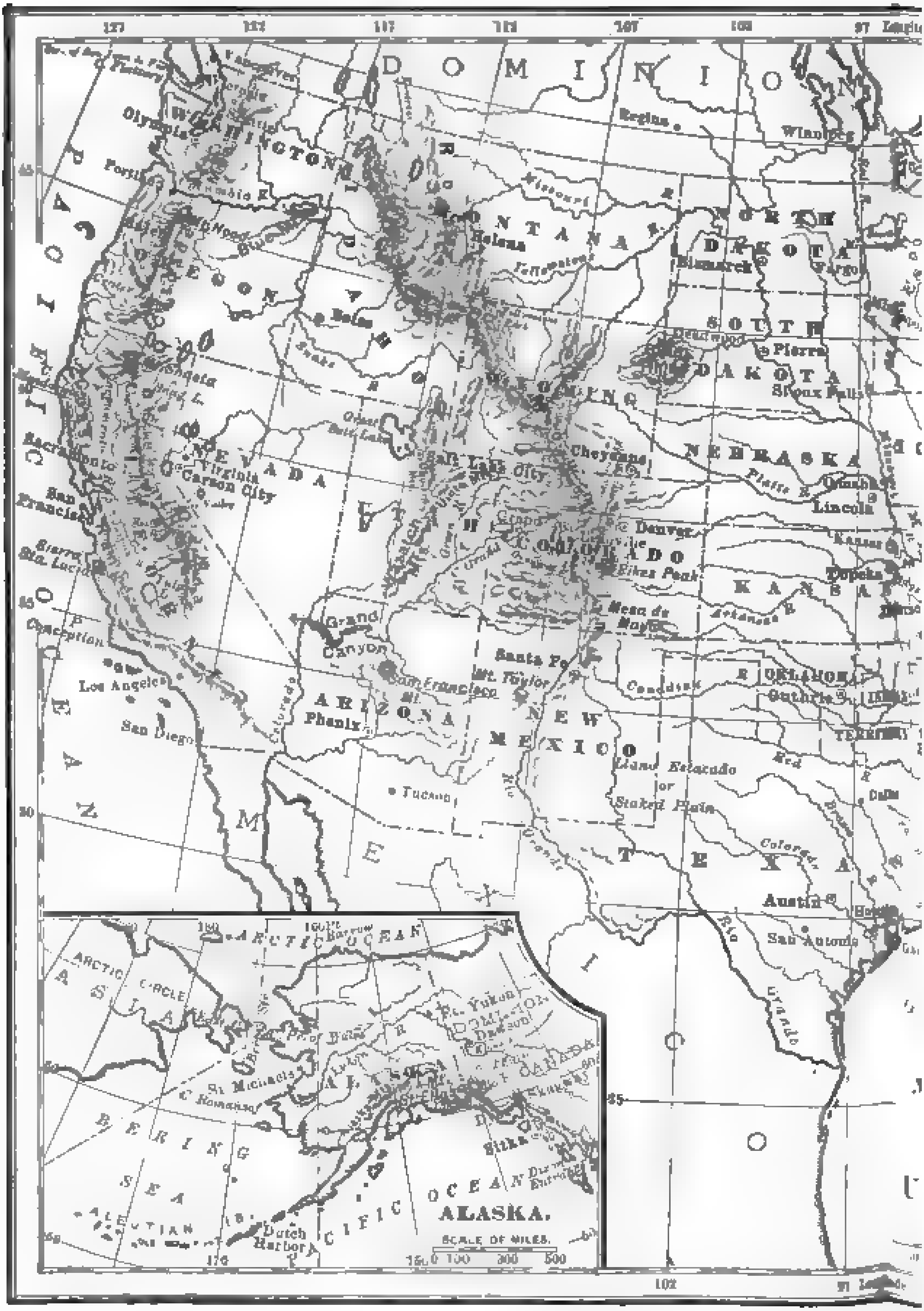

THE CHIEF PHYSICAL DIVISIONS OF THE
UNITED STATES
SCALE OF MILES
A: Adirondack Mountains
B: Black Hills
ATLANTIC OCEAN
GULF OF MEXICO
PACIFIC OCEAN
ALLEGHENY PLATEAU
OZARK PLATEAU
OUACHITA MTNS.
Mississippi
Missouri
THE GREAT PLAINS
COLORADO PLATEAUS
LAVA PLATEAU
RANGES

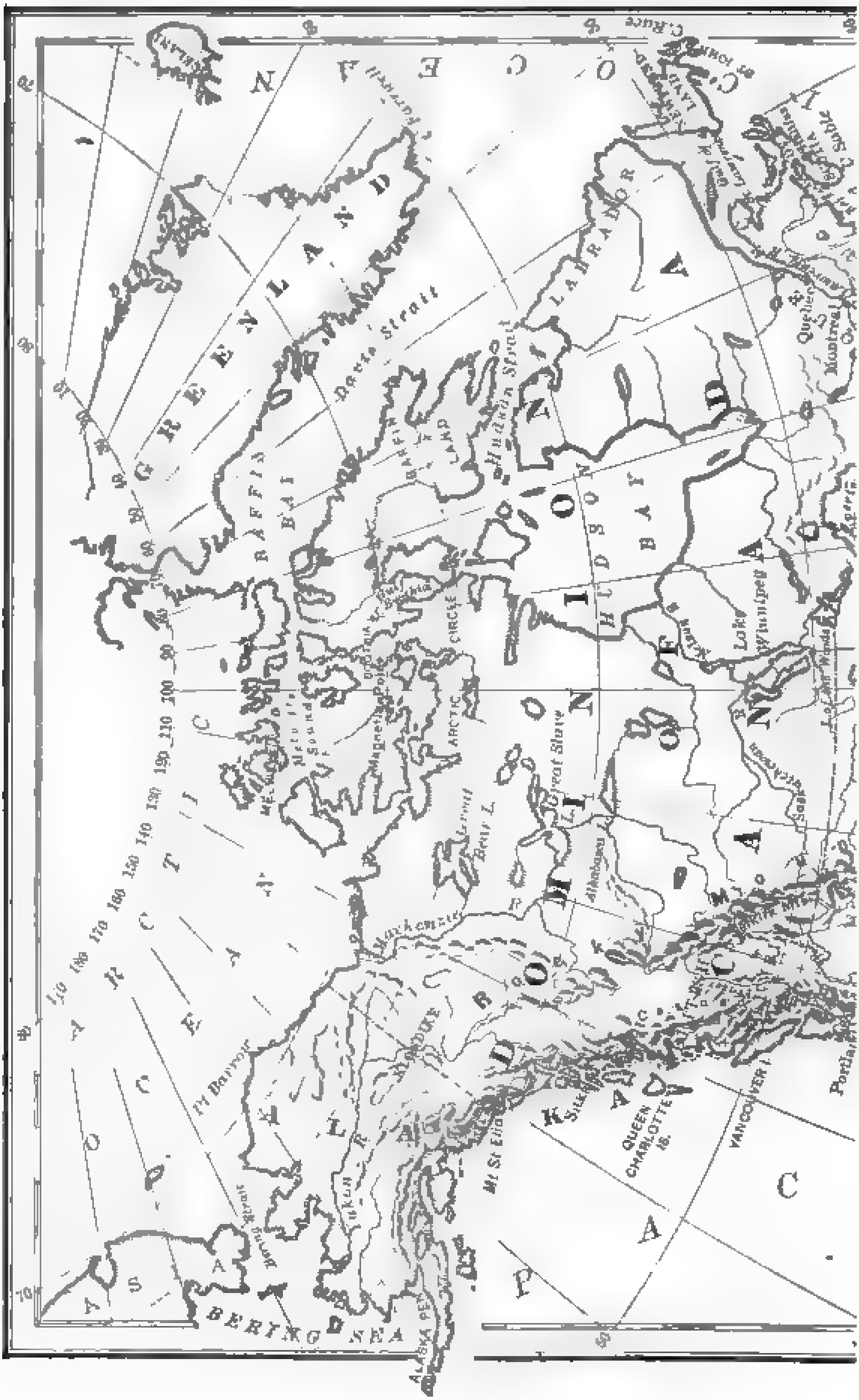
PLATE C.



D O M I N I O N
Regina
Winnipeg
Olympia
WASHINGTON
Portland
Columbia R.
Mt. Hood
Blue Mts.
MONTANA
Helena
Missouri R.
Yellowstone
NORTH DAKOTA
Bismarck
Fargo
OREGON
Boise
IDAHO
Snake R.
SOUTH DAKOTA
Deadwood
Pierre
Sioux Falls
Shasta
WYOMING
Great Salt Lake
NEVADA
Sacramento
Virginia
Carson City
San Francisco
Salt Lake City
UTAH
Cheyenne
NEBRASKA
Platte R.
Omaha
Lincoln
Denver
COLORADO
Pikes Peak
Kansas
Topeka
KANSAS
Arkansas R.
Sierra
Sta. Lucia
Conception
Grand Canyon
Mesa de Mayo
Santa Fe
Mt. Taylor
San Francisco Mt.
Los Angeles
San Diego
ARIZONA
Phœnix
Colorado
NEW MEXICO
Canadian
OKLAHOMA
Guthrie
TERRITORY
Red R.
Llano Estacado or Staked Plain
Tucson
Rio Grande
TEXAS
Colorado
Austin
San Antonio
Rio Grande
M E X I C O
P A C I F I C O C E A N
ARCTIC OCEAN
Pt. Barrow
ARCTIC CIRCLE
ASIA
Ft. Yukon
DOMINION
Dawson
CANADA
St. Michaels
C. Romanzof
ALASKA
BERING SEA
Sitka
ALEUTIAN IS.
Dutch Harbor
PACIFIC OCEAN
Dixon Entrance
ALASKA.
SCALE OF MILES.
0 100 300 500
127
122
117
112
107
102
97
Longitude
Latitude


West from Greenwich
77
72
67
Gulf of St. Lawrence
Lake of the Woods
L. Superior
Duluth
Quebec
Montreal
OTTAWA
Toronto
L. Ontario
L. Huron
L. Michigan
L. Erie
St. Paul
WISCONSIN
Milwaukee
Madison
Chicago
Lansing
Detroit
Des Moines
Portland
Concord
Boston
Providence
Newport
New York
Trenton
Philadelphia
Atlantic City
Pittsburg
Harrisburg
Baltimore
Dover
WASHINGTON
OHIO
Wheeling
Columbus
Cincinnati
Springfield
ILLINOIS
Indianapolis
Kansas City
St. Louis
VIRGINIA
Charleston
Richmond
Norfolk
Frankfort
Louisville
Mammoth Cave
Cairo
Ozark Mts.
Petersburg
Raleigh
Nashville
TENNESSEE
Little Rock
Wilmington
Columbia
Atlanta
Charleston
Savannah
ALABAMA
GEORGIA
Montgomery
Jackson
Jacksonville
St. Augustine
Baton Rouge
Tallahassee
New Orleans
Galveston
Tampa
Key West
GULF OF MEXICO
UNITED STATES.
SCALE OF MILES
100 200 300 400 500 600
West 92 from Greenwich 87
DOMINION CANADA
MAINE
Augusta
Portland
Concord
Albany
MASSACHUSETTS
Boston
Hartford
Providence
Newport
West Point
New York
Long Branch
Trenton
Philadelphia
Atlantic City
Baltimore
Annapolis
Dover
WASHINGTON
Richmond
Norfolk
ATLANTIC OCEAN
NEW ENGLAND
and Coast of
Middle Atlantic States.
(On Enlarged Scale.)
SCALE OF MILES
0 25 50 100 150 200

PLATE D.


GREENLAND
BAFFIN BAY
Davis Strait
BAFFIN LAND
Hudson Strait
LABRADOR
HUDSON BAY
DOMINION OF CANADA
ARCTIC OCEAN
ARCTIC CIRCLE
Lake Winnipeg
Great Slave L.
Great Bear L.
Athabasca
Saskatchewan
Mackenzie
Quebec
Montreal
Portland
Pt Barrow
Bering Strait
BERING SEA
ALASKA
ALASKA PEN.
Mt St Elias
Sitka
QUEEN CHARLOTTE IS.
VANCOUVER I.
PACIFIC
C. Race

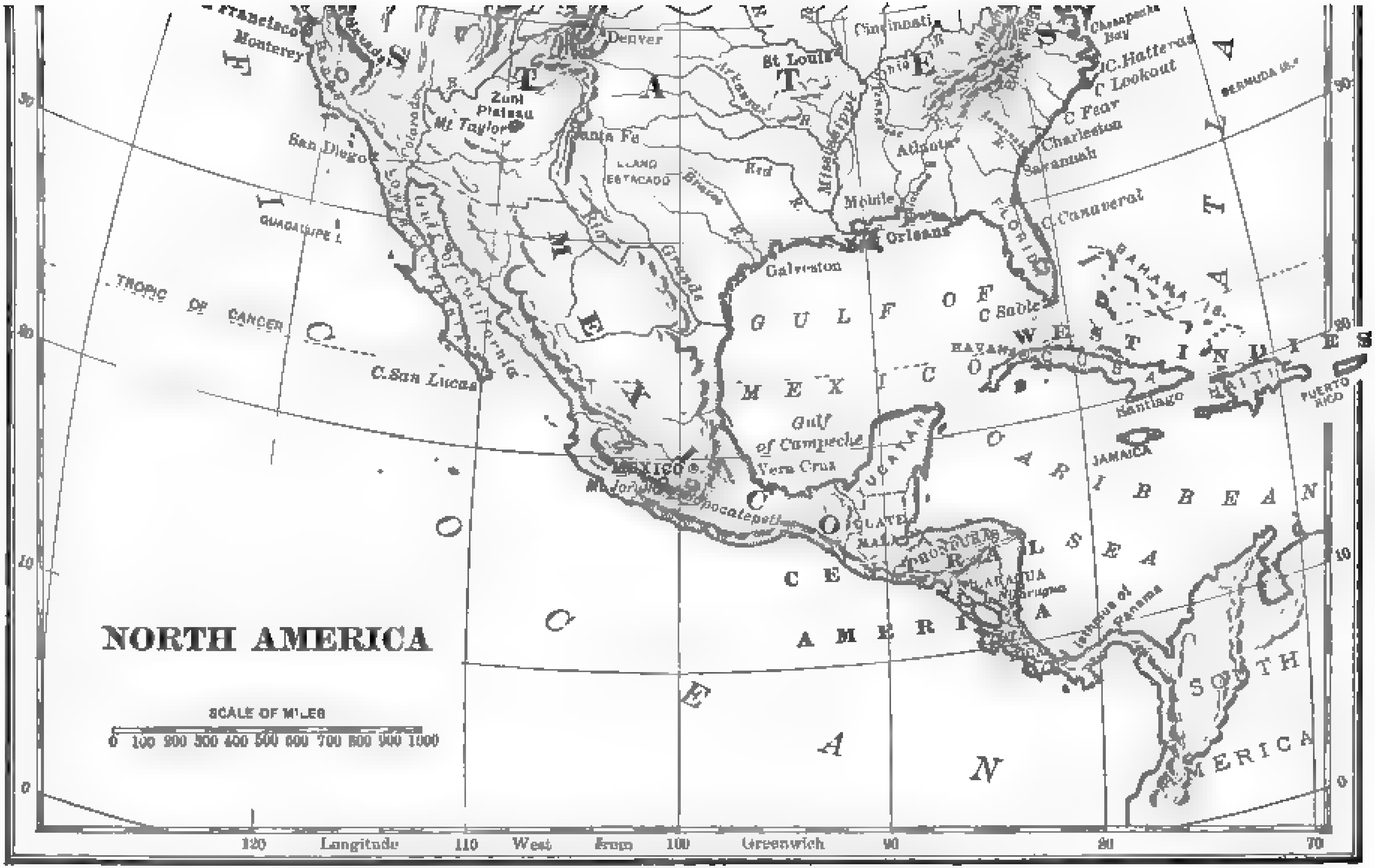
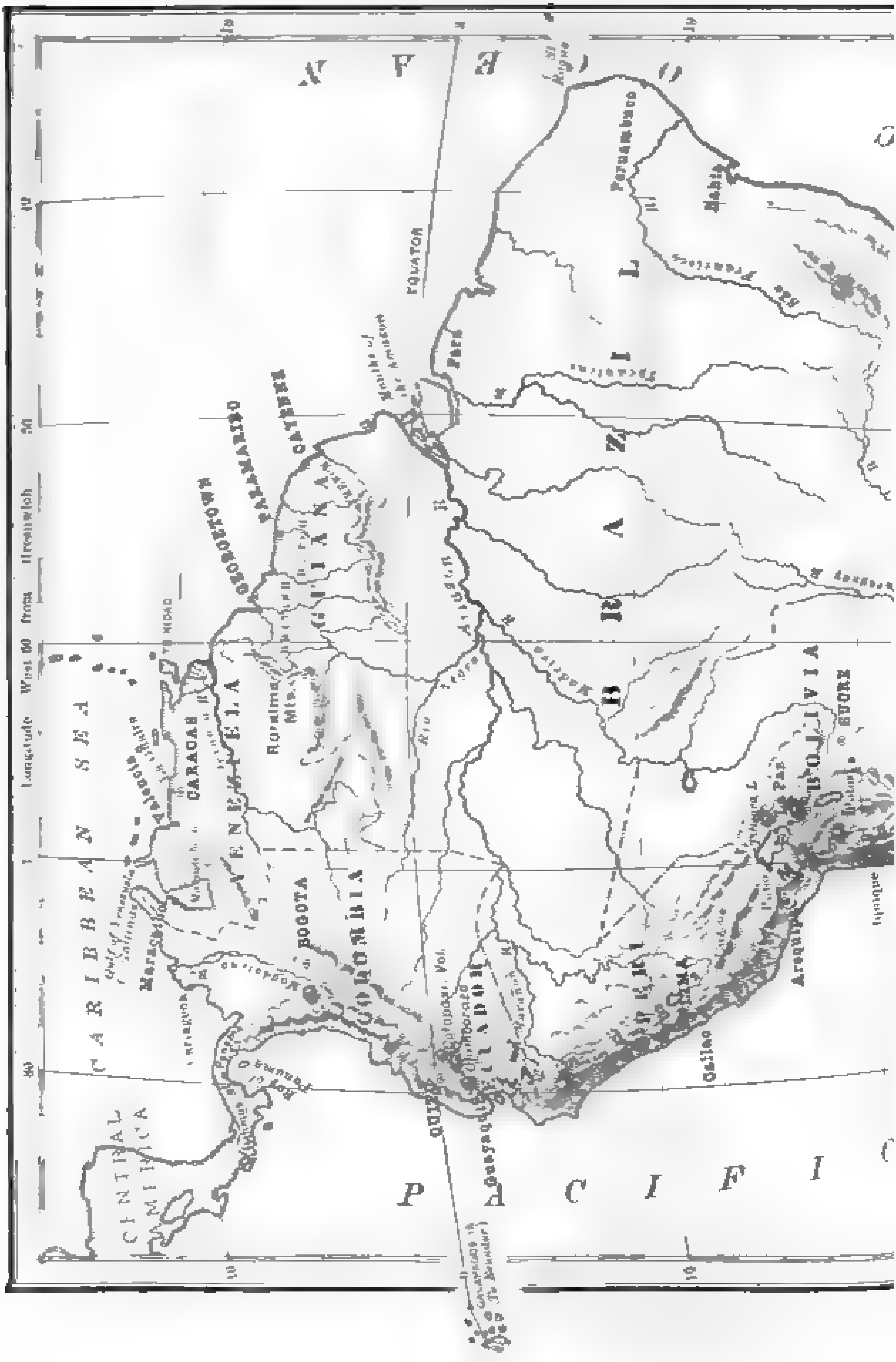

NORTH AMERICA
SCALE OF MILES
0 100 200 300 400 500 600 700 800 900 1000
Longitude West from Greenwich
GULF OF MEXICO
CARIBBEAN SEA
WEST INDIES
Gulf of Campeche
Gulf of California
TROPIC OF CANCER
Denver
St Louis
Cincinnati
Mobile
Galveston
Vera Cruz
Santa Fe
Zuni Plateau
Mt Taylor
San Diego
Monterey
C.San Lucas
C Sable
C.Canaveral
Charleston
Savannah
C Fear
C Lookout
C.Hatteras
Chesapeake Bay
JAMAICA
HAITI
PUERTO RICO
Santiago
HAVANA
Atlanta
LLANO ESTACADO
SOUTH AMERICA
CENTRAL AMERICA

PLATE E.


CARIBBEAN SEA
CENTRAL AMERICA
PACIFIC
VENEZUELA
CARACAS
TRINIDAD
Maracaibo
COLOMBIA
BOGOTA
GEORGETOWN
PARAMARIBO
CAYENNE
GUIANA
Roraima Mts.
BRAZIL
Pará
Pernambuco
Bahia
EQUATOR
QUITO
Guayaquil
ECUADOR
PERU
LIMA
Callao
Arequipa
BOLIVIA
SUCRE
Longitude West 60 from Greenwich

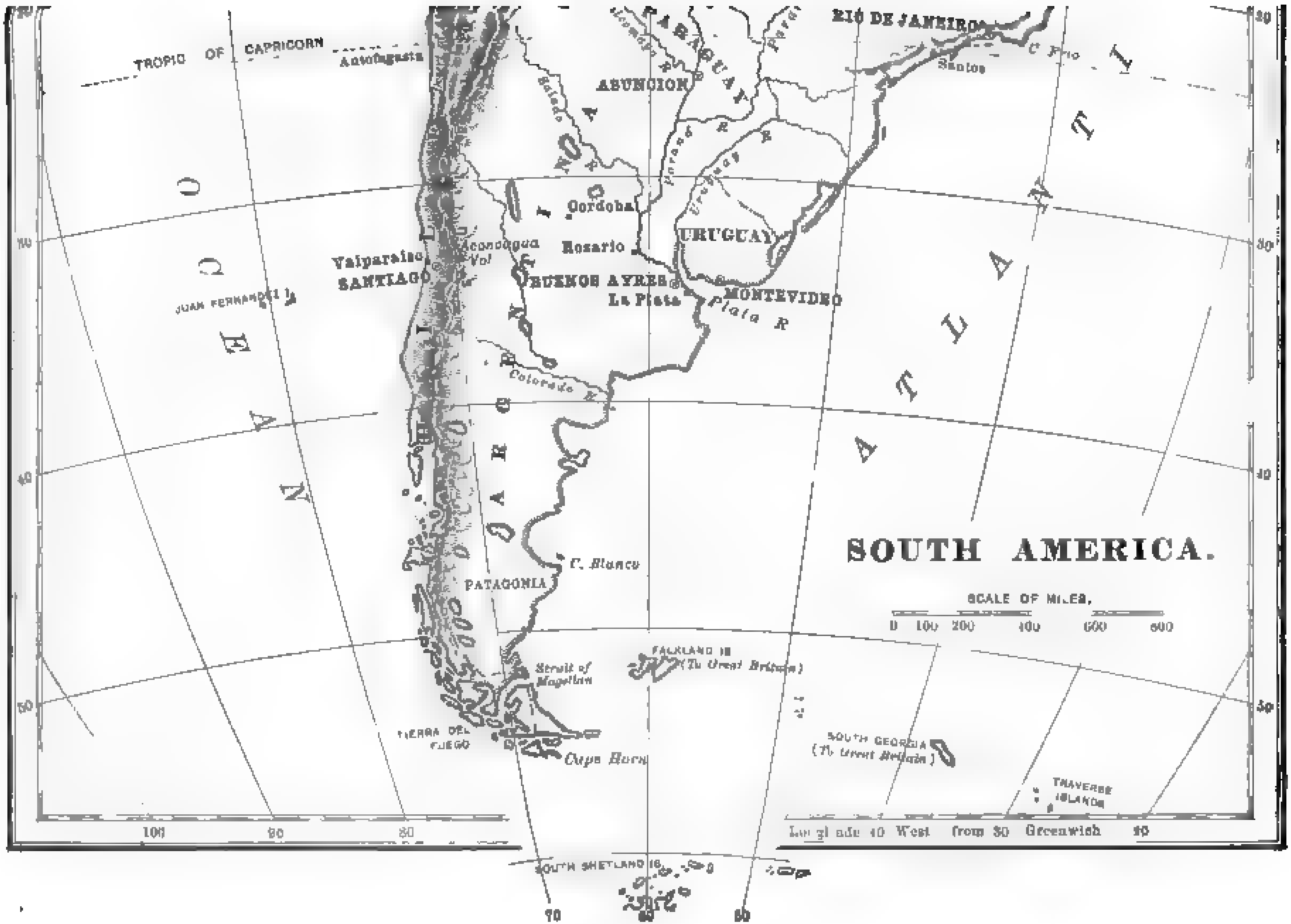
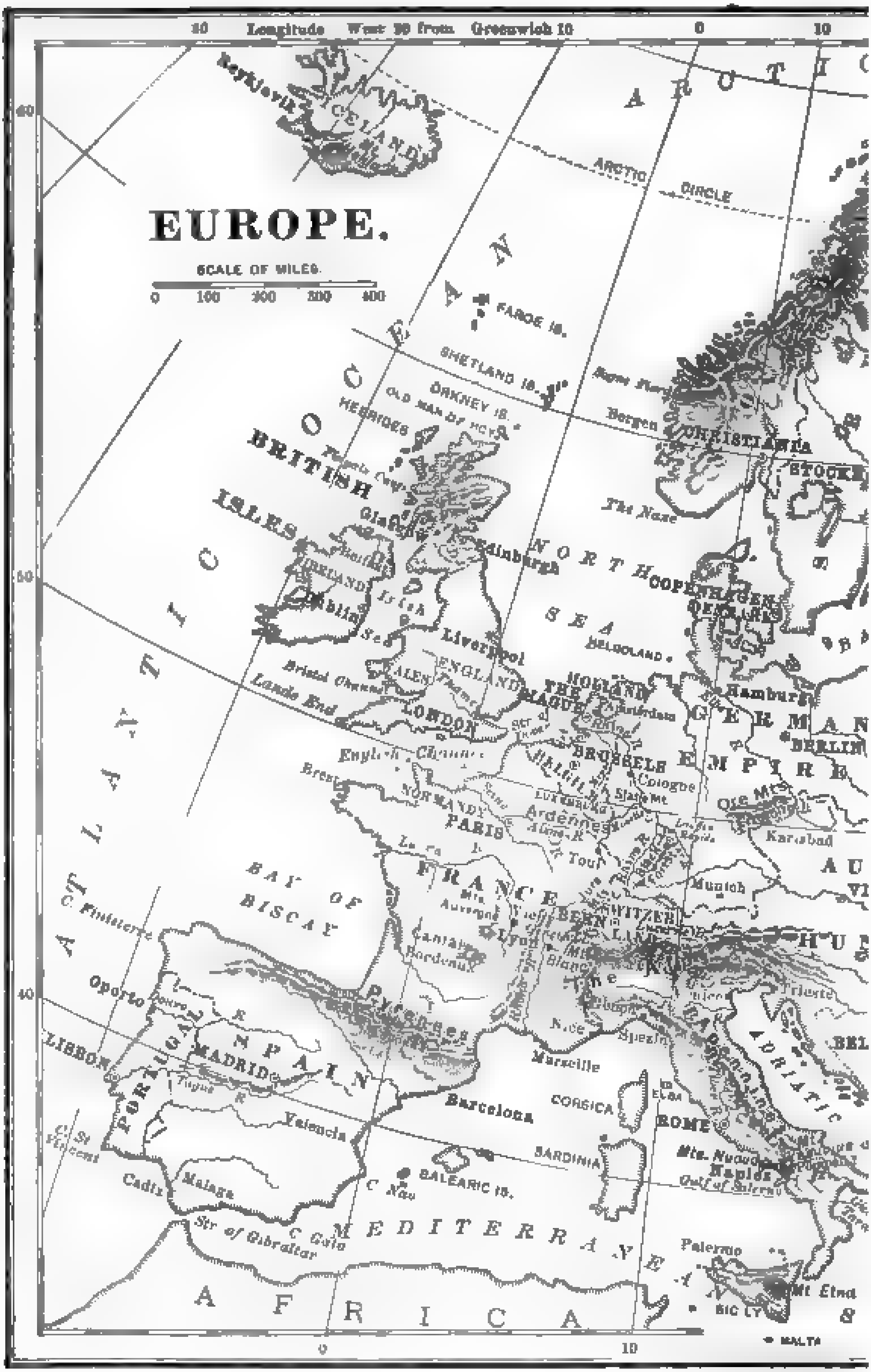

SOUTH AMERICA.
SCALE OF MILES.
0 100 200 400 600 800
TROPIC OF CAPRICORN
Antofagasta
RIO DE JANEIRO
Santos
C. Frio
ASUNCION
PARAGUAY
Cordoba
Rosario
URUGUAY
BUENOS AYRES
La Plata
MONTEVIDEO
Plata R.
Valparaiso
SANTIAGO
Aconcagua Vol.
JUAN FERNANDEZ I.
Colorado R.
C. Blanco
PATAGONIA
Strait of Magellan
TIERRA DEL FUEGO
Cape Horn
FALKLAND IS. (To Great Britain)
SOUTH GEORGIA (To Great Britain)
TRAVERSE ISLANDS
SOUTH SHETLAND IS.
O C E A N
A T L A N T I
Greenwich

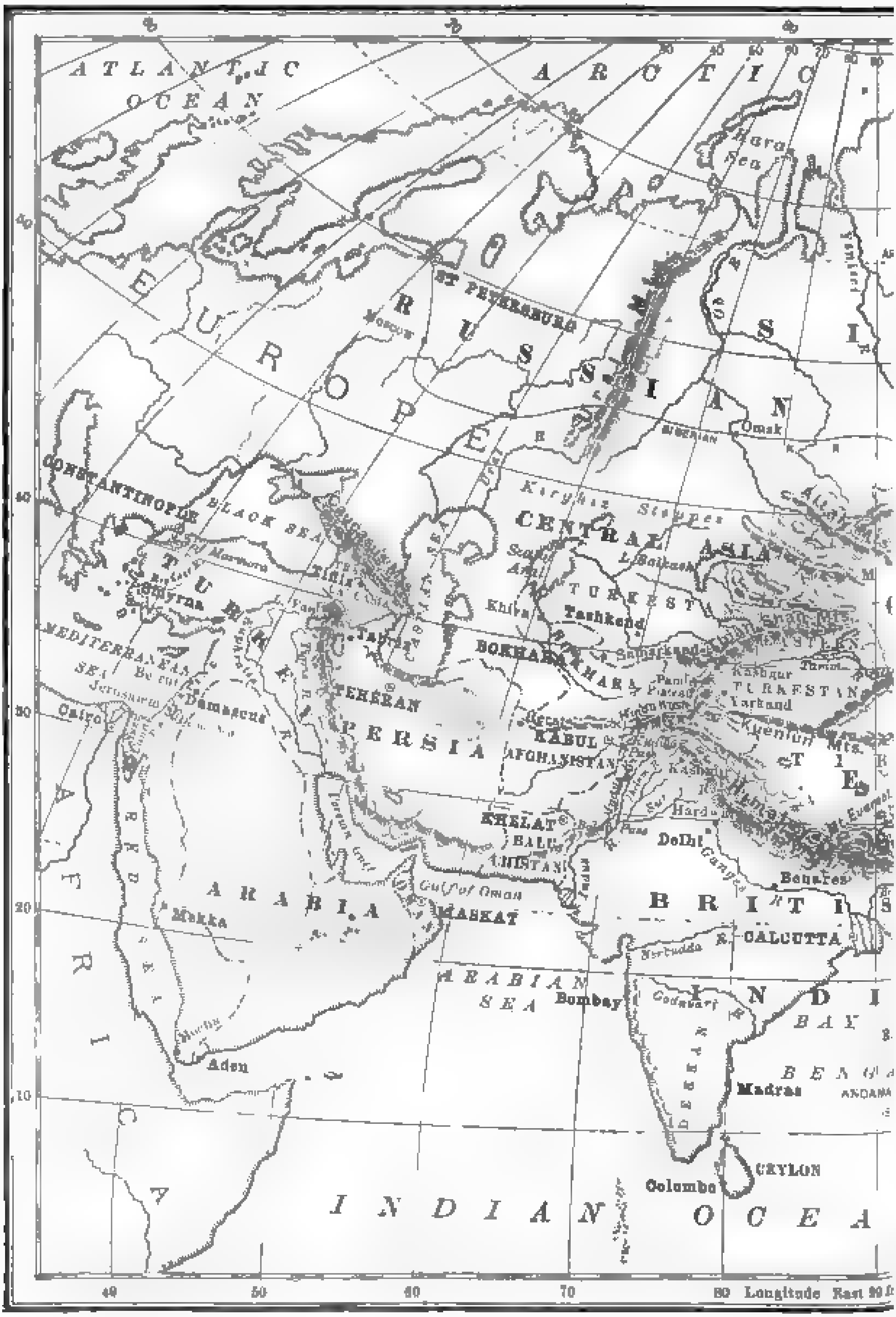
PLATE F.



EUROPE.
SCALE OF MILES.
0 100 200 300 400
Longitude West 20 from Greenwich 10
ARCTIC CIRCLE
A T L A N T I C O C E A N
ICELAND
FAROE IS.
SHETLAND IS.
ORKNEY IS.
HEBRIDES
BRITISH ISLES
Glasgow
Edinburgh
IRELAND
Dublin
Irish Sea
Liverpool
ENGLAND
WALES
Bristol Channel
Lands End
LONDON
English Channel
Bergen
CHRISTIANIA
The Naze
N O R T H S E A
HELGOLAND
COPENHAGEN
Hamburg
HOLLAND
THE HAGUE
BRUSSELS
Cologne
G E R M A N E M P I R E
BERLIN
Karlsbad
Munich
Brest
NORMANDY
PARIS
Ardennes
FRANCE
BAY OF BISCAY
C. Finisterre
Bordeaux
Lyon
BERN
Mt. Blanc
Marseille
Nice
Spezia
Oporto
LISBON
PORTUGAL
MADRID
S P A I N
Valencia
Barcelona
Cadiz
Malaga
C. St. Vincent
Str. of Gibraltar
BALEARIC IS.
CORSICA
SARDINIA
ELBA
ROME
Naples
Gulf of Salerno
Trieste
ADRIATIC
Palermo
Mt. Etna
SICILY
MALTA
M E D I T E R R A N E A N
A F R I C A

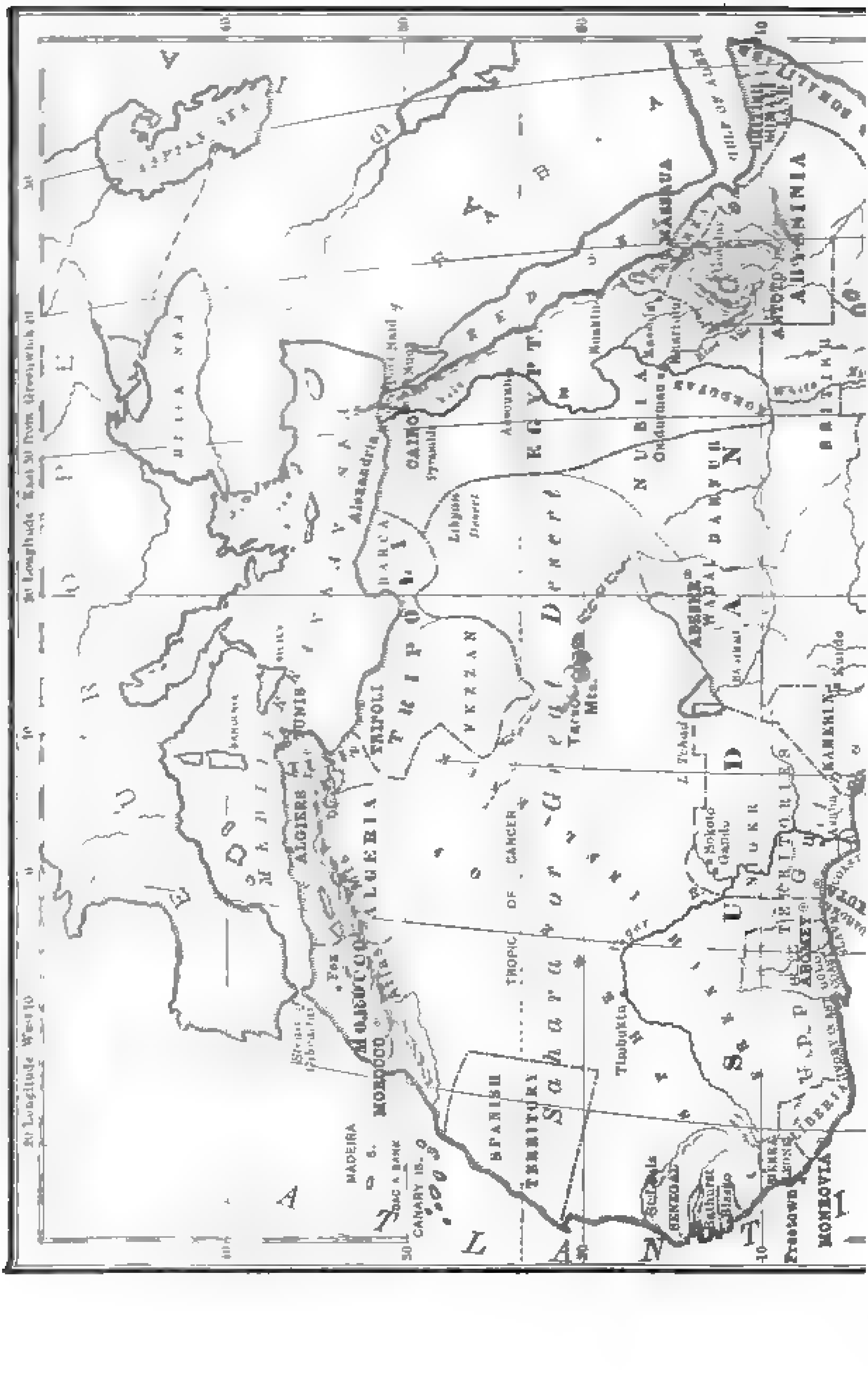
Longitude 30 East from 40 Greenwich 50
70
60
50
40
LAPLAND
White Sea
Archangel
Dwina R
L. Onega
L. Ladoga
Gulf of Finland
ST. PETERSBURG
Nizhni Novgorod
Riga
Moscow
R U S S I A
Ural River
Volga
Warsaw
Dnieper R
Don R
Astrakhan
Sea of Azof
Odessa
Pruth R
Karpathian
Transylvanian
BUKHAREST
Danube
BULGARIA
TURKEY
BLACK SEA
CONSTANTINOPLE
CASPIAN SEA
Tiflis
A S I A M I N O R
AEGEAN
ATHENS
CRETE
A S I A
30 Longitude East from Greenwich 40

PLATE G.


ATLANTIC
OCEAN
ARCTIC
Kara Sea
EUROPE
RUSSIA
ST PETERSBURG
Moscow
Omsk
CONSTANTINOPLE
BLACK SEA
Kirghiz Steppes
CENTRAL ASIA
Aral
L. Balkash
TURKESTAN
Tiflis
Smyrna
Khiva
Tashkend
TURKEY
Tabriz
BOKHARA
Samarkand
MEDITERRANEAN
SEA
Beirut
Damascus
Jerusalem
TEHERAN
Kashgar
TURKESTAN
Yarkand
Cairo
PERSIA
KABUL
AFGHANISTAN
Kuenlun Mts.
TIBET
Persian Gulf
KHELAT
BALUCHISTAN
Delhi
Ganges
Benares
AFRICA
ARABIA
Mekka
Gulf of Oman
MASKAT
BRITISH
CALCUTTA
Red Sea
ARABIAN
SEA
Bombay
INDIA
Aden
BAY
BENGAL
Madras
CEYLON
Colombo
INDIAN
OCEAN
40
50
60
70
80
Longitude East

Longitude East from Greenwich
OCEAN
NEW SIBERIA
ALASKA
BERING SEA
ALEUTIAN
ARCTIC CIRCLE
Yakutsk
Lena R.
SIBERIA
EMPIRE
OKHOTSK SEA
SAKHALIN
L. Baikal
Irkutsk
Kiakhta
Amur R.
MANCHURIA
Urga
MONGOLIA
CHINESE EMPIRE
Desert of Gobi
Mukden
YESSO
Vladivostok
JAPAN SEA
PEKIN
Port Arthur
SEOUL
HONDO
TOKYO
Yokohama
Tientsin
GREAT WALL
SHANTUNG
Kiao-chau
Yellow Sea
Hoangho R.
Shanghai
EMPIRE OF JAPAN
PACIFIC OCEAN
Yangtse
CHINA
Nanling Mts.
TROPIC OF CANCER
FORMOSA
Canton
Macao
Hongkong
UPPER BURMA
Mandalay
Hanoi
FRENCH INDO-CHINA
HAINAN
SIAM
BANGKOK
HUE
PHILIPPINE ISLANDS
MANILA
CHINA SEA
Saigon
Gulf of Siam
MALAY PENINSULA
SUMATRA
Singapore
BORNEO
ASIA.
SCALE OF MILES.
0 200 400 600 800 1000
Greenwich 100 110 120 130 140

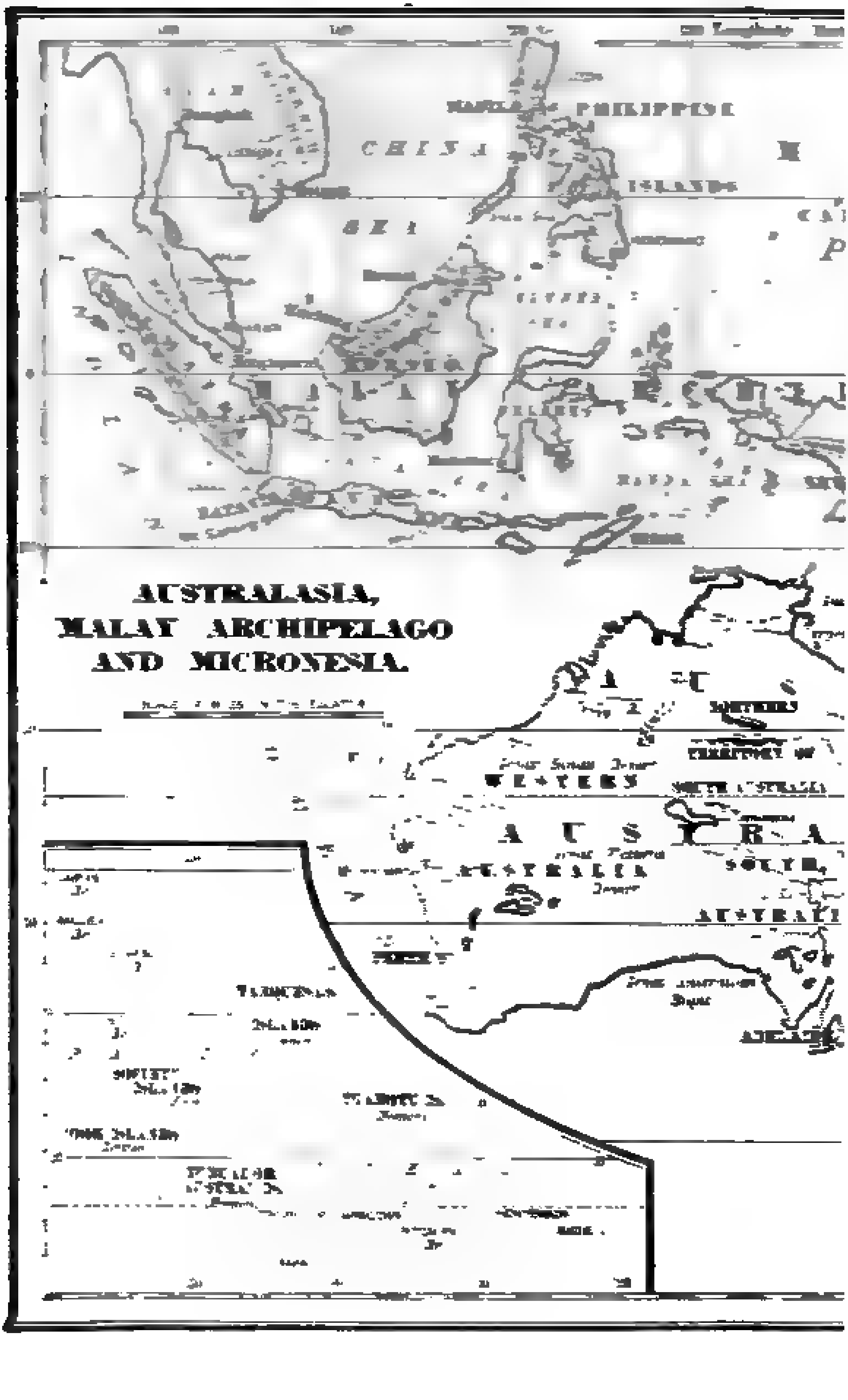
PLATE II.

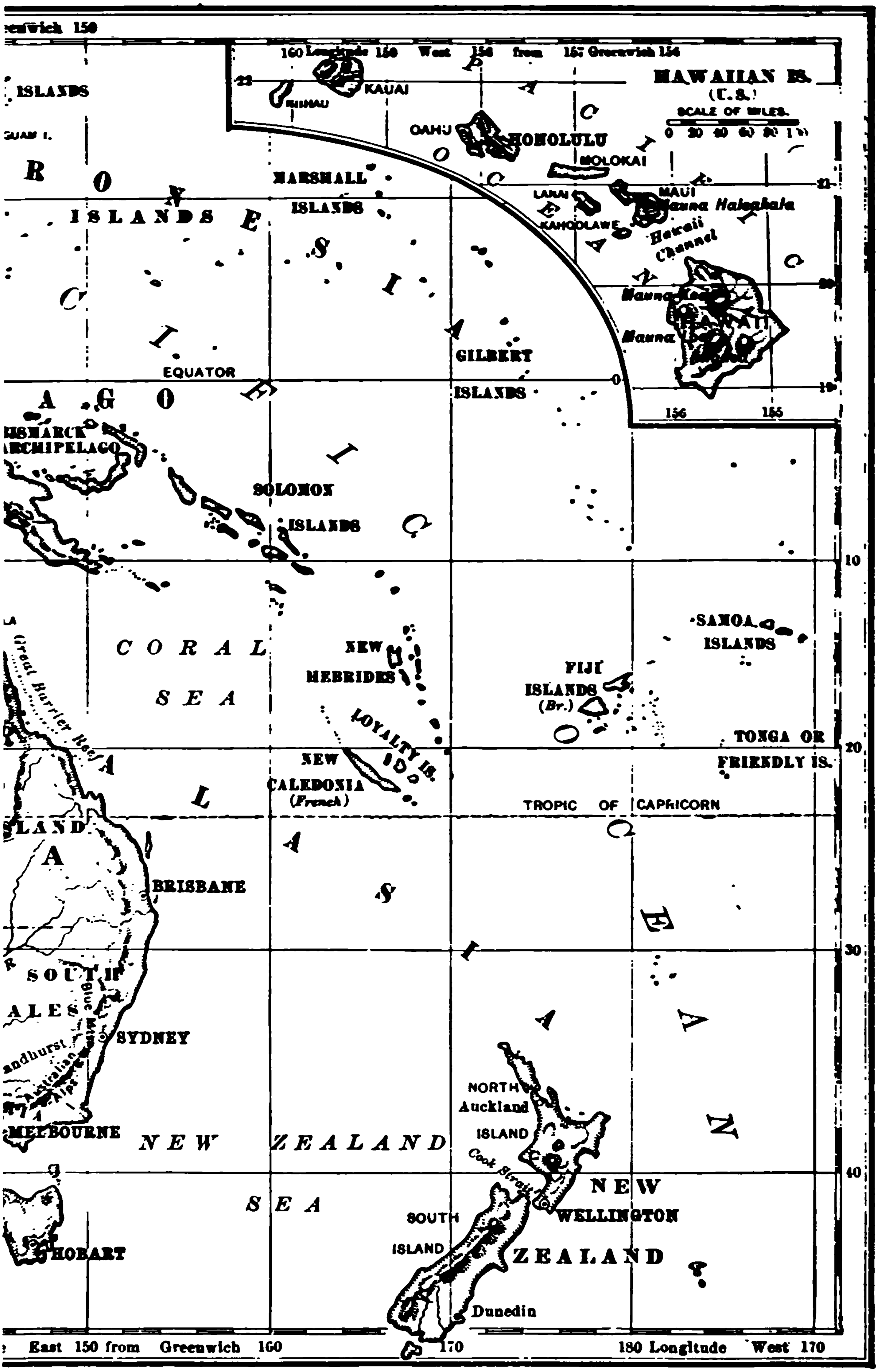


EGYPT
NUBIA
ABYSSINIA
CAIRO
Alexandria
TRIPOLI
TUNIS
ALGIERS
ALGERIA
MOROCCO
SPANISH TERRITORY
Timbuktu
MADEIRA
CANARY IS.
SENEGAL
MONROVIA
TROPIC OF CANCER

AFRICA.
SCALE OF MILES
0 200 400 600 800 1000 1200
GULF OF GUINEA
EQUATOR
LIBREVILLE
FRENCH KONGO
KONGO FREE STATE
Stanley Falls
Albert Nyanza
Victoria Nyanza
Mt. Kenia
Mt. Kilimanjaro
GERMAN EAST AFRICA
MOMBASA
ZANZIBAR
BAGAMOYO
BOMA
Leopoldville
Tanganyika
LOANDA
PORTUGUESE WEST AFRICA
Benguela
BRITISH CENTRAL AFRICA
ZAMBESIA
Lake Nyassa
PORTUGUESE EAST AFRICA
MOZAMBIQUE
MOZAMBIQUE CHANNEL
MADAGASCAR
ANTANANARIVO
MAURITIUS
ST. HELENA
TROPIC OF CAPRICORN
GERMAN SOUTH-WEST AFRICA
BRITISH SOUTH AFRICA
Walfisch Bay
Kalahari Desert
TRANSVAAL
PRETORIA
Johannesburg
LOURENÇO MARQUEZ
ANGRA PEQUEÑA
ORANGE FREE STATE
Kimberley
Pietermaritzburg
BLOEMFONTEIN
CAPE COLONY
CAPE TOWN
Cape of Good Hope
INDIAN OCEAN
20 Longitude West 10
0
10
20 Longitude East 30 from Greenwich 40
50

PLATE I.


AUSTRALASIA,
MALAY ARCHIPELAGO
AND MICRONESIA.
PHILIPPINE
ISLANDS
CHINA
SEA
BANDA SEA
WESTERN
AUSTRALIA
SOUTH
NORTHERN
TERRITORY OF
SOUTH AUSTRALIA
PERTH
ADELAIDE



HAWAIIAN IS.
(U.S.)
SCALE OF MILES
KAUAI
OAHU
HONOLULU
MOLOKAI
LANAI
MAUI
KAHOOLAWE
Mauna Haleakala
Hawaii Channel
Mauna Kea
HAWAII
Mauna Loa
ISLANDS
GUAM I.
MARSHALL ISLANDS
GILBERT ISLANDS
EQUATOR
BISMARCK ARCHIPELAGO
SOLOMON ISLANDS
CORAL SEA
NEW HEBRIDES
LOYALTY IS.
NEW CALEDONIA
(French)
Great Barrier Reef
FIJI ISLANDS
(Br.)
SAMOA ISLANDS
TONGA OR FRIENDLY IS.
TROPIC OF CAPRICORN
BRISBANE
SYDNEY
MELBOURNE
HOBART
Australian Alps
NEW ZEALAND SEA
NORTH ISLAND
Auckland
Cook Strait
WELLINGTON
SOUTH ISLAND
NEW ZEALAND
Dunedin
PACIFIC OCEAN
East 150 from Greenwich 160
170
180 Longitude West 170
10
20
30
40

Doldrums - equatorial calm belt on sea.
Horse latitudes - between trades & prevailing we

	DATE DUE		
JUN 1 1 1987			